

7n5B

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY—BULLETIN NO. 56.

D. E. SALMON, D. V. M., Chief of Bureau.

DIGESTION EXPERIMENTS WITH POULTRY.

BY

E. W. BROWN, PH. D.,

Assistant in the Biochemic Division.

PREPARED UNDER THE SUPERVISION OF

E. A. DE SCHWEINITZ, PH. D.,

Chief of Biochemic Division of the Bureau of Animal Industry.



APR 23 1904

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1904.

ORGANIZATION OF THE BUREAU OF ANIMAL INDUSTRY.

Chief: D. E. SALMON, D. V. M.

Assistant Chief: A. D. MELVIN, D. V. S.

Chief Clerk: E. B. JONES, L.L. M., M. D.

Dairy Division: HENRY E. ALVORD, C. E., chief; CLARENCE B. LANE, B. S., assistant chief.

Inspection Division: A. M. FARRINGTON, B. S., D. V. M., chief.

Quarantine Division: RICHARD W. HICKMAN, Ph. G., V. M. D., chief.

Editor: GEORGE FAYETTE THOMPSON, M. S.

Artist: W. S. D. HAINES.

Expert in Animal Husbandry: GEORGE M. ROMMEL, B. S. A.

Librarian: BEATRICE C. OBERLY.

LABORATORIES.

Biochemic Division: MARION DORSET, M. D., chief.

Pathological Division: JOHN R. MOHLER, A. M., V. M. D., chief; HENRY J. WASHBURN, D. V. S., acting assistant chief.

Zoological Division: CH. WARDELL STILES,^a M. S., A. M., Ph. D., consulting zoologist in charge.

EXPERIMENT STATION.

Superintendent, E. C. SCHROEDER, M. D. V.; expert assistant, W. E. COTTON.

INSPECTORS IN CHARGE.

Dr. F. W. Ainsworth, Union Stock Yards, Pittsburg, Pa.

Dr. M. O. Anderson, care Geo. A. Hormel & Co., Austin, Minn.

Dr. Don C. Ayer, Post-Office Building, South Omaha, Nebr.

Dr. G. S. Baker, 6th and Townsend sts., San Francisco, Cal.

Dr. L. R. Baker, South St. Joseph, Mo.

Dr. Boyd Baldwin, care Cudahy Bros., Cudahy, Wis.

Dr. A. E. Behnke, room 434 Federal Building, Milwaukee, Wis.

Dr. John A. Bell, Watertown, N. Y.

Dr. S. E. Bennett, room 338, Live Stock Exchange, Kansas City, Kans.

Dr. Eli L. Bertram, Tri-City Packing Co., Davenport, Iowa.

Dr. Richard J. Blanche, care Brittain & Co., Marshalltown, Iowa.

Dr. Fred Braginton, care Continental Packing Co., Bloomington, Ill.

Dr. J. J. Brougham, care Missouri Stock Yards, St. Louis, Mo.

Dr. G. W. Butler, care Drummond Bros., Eau Claire, Wis.

Dr. J. B. Clancy, National Stock Yards, Ill.

Dr. Charles Cowie, Ogdensburg, N. Y.

Dr. David Cumming, 912 Lapeer ave., Port Huron, Mich.

Dr. Robert Darling, care Chas. S. Hardy, San Diego, Cal.

Dr. E. T. Davison, Rushville, Nebr.

Dr. J. F. Deadman, Sault Ste. Marie, Mich.

Mr. Albert Dean, room 328, Stock Yard Station, Kansas City, Kans.

Dr. F. L. De Wolf, care Chas. Wolff Packing Co., Topeka, Kans.

Dr. Geo. Ditewig, care Union Stock Yards, Cincinnati, Ohio.

Dr. E. P. Dowd, care White, Pevey & Dexter Co., Worcester, Mass.

Dr. O. E. Dyson, 316 Exchange Building, Union Stock Yards, Chicago, Ill.

Dr. Geo. C. Faville, Box 796, Norfolk, Va.

Dr. N. K. Fegley, care Sperry & Barnes, New Haven, Conn.

Dr. T. A. Geddes, care U. S. consul, London, England.

Dr. H. H. George, 507 Johnson st., Louisville, Ky.

Dr. W. H. Gibbs, care Morton-Gregson Co., Nebraska City, Nebr.

Dr. L. K. Green, care Hammond, Standish & Co., Detroit, Mich.

Dr. H. A. Hedrick, 215 St. Paul st., Baltimore, Md.

Dr. O. B. Hess, care Frye-Bruhn Co., Seattle, Wash.

Mr. G. S. Hickox, P. O. box 1145, Salt Lake City, Utah.

Dr. Julius Huelson, care The Jersey City Stock Yard Co., Jersey City, N. J.

Dr. F. W. Huntington, G. T. R. K. Building, Portland, Me.

Dr. G. A. Johnson, Exchange Building, Sioux City, Iowa.

Dr. James Johnson, care U. S. consul, Liverpool, England.

Dr. Charles Keane, care Cudahy Packing Co., Los Angeles, Cal.

(Continued on third page of cover.)

^aTransferred, August 16, 1902, to the U. S. Public Health and Marine-Hospital Service, as Chief of Division of Zoology, but remains also in temporary charge of Zoological Division, Bureau of Animal Industry.

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY—BULLETIN NO. 56.

D. E. SALMON, D. V. M., Chief of Bureau.

DIGESTION EXPERIMENTS WITH POULTRY.

BY

E. W. BROWN, PH. D.,

Assistant in the Biochemic Division.

PREPARED UNDER THE SUPERVISION OF

E. A. DE SCHWEINITZ, PH. D.,

Chief of Biochemic Division of the Bureau of Animal Industry.



WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1904.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., December 22, 1903.

SIR: I have the honor to transmit herewith a manuscript entitled "Digestion Experiments with Poultry," by E. W. Brown, Ph. D., assistant in the Biochemic Division, and recommend its publication as Bulletin No. 56 of this Bureau. These tests were carried out with the object of determining the digestibility of corn, oats, wheat, and meat, respectively, for chickens. The investigations heretofore published along this line for poultry are very limited, especially when compared with those for mammals. The difficulties attendant upon experiments of this nature with the former class of animals, owing to their physiological formation, are no doubt largely accountable for the small amount of literature extant upon the subject. Hence the present volume is of timely interest.

Some practical suggestions to poultrymen are included, bearing on the dietary values of the different properties of the foods above mentioned, and also on the digestive value of the grains when used in combination.

The four half-tones and two text figures are necessary as illustrations.

Respectfully,

D. E. SALMON,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary.

CONTENTS.

	Page.
Prefatory	7
Introduction	7
Purpose of the present paper	9
Certain features of nitrogenous metabolism in birds.....	9
Differences between the nitrogenous end-products of birds and mam- mals	9
The place of formation of uric acid in birds.....	11
The antecedents of uric-acid production.....	14
Review of the literature on the digestive secretions of birds.....	16
The crop, esophagus, proventriculus, and gizzard.....	16
The gastric juice.....	17
The pancreatic juice	19
Review of the literature on the digestibility of poultry foodstuffs	20
Meat as a sole diet for poultry	22
The glycogen formation in birds.....	23
Routine and methods of present experiments.....	24
Management of the chickens.....	26
The apparatus for collection of the excrement.....	27
Method of preservation of the excrement	28
The methods of analysis adopted	29
Preparation and sampling of the food and excrement	29
Organic matter	31
Crude proteid	31
Metabolic and "Residual" nitrogen.....	33
Uric acid	34
Ether extract	41
Ammonia.....	42
Crude fiber	42
Pentosans.....	42
Nitrogen-free extract	42
Soluble ash and silica.....	43
Details of the present experiments.....	43
General scheme of the experiments.....	43
Composition of the food and excrement.....	44
The corn experiments	44
Digestion coefficients	44
The oats experiments.....	50
Digestion coefficients	51
The wheat experiments.....	53
Digestion coefficients	54
The meat experiments.....	55
Digestion coefficients	55
Comparison with grain coefficients.....	56

Details of the present experiments—Continued.	Page.
The metabolic nitrogen of the excrement	57
A comparison of the present with previous experiments	59
Experiments with corn	59
Experiments with oats	62
Experiments with wheat	62
Experiments with peas and barley	63
The digestion coefficients of poultry and other farm animals compared	63
General discussion of the digestion coefficients	65
Some practical aspects of the results	66
Feeding standards based on the digestion coefficients	66
The cost of the principal nutrients	69
Body weights and cost of assimilated nutrients	69
The use of the grains in combination	71
The utilization of sand by poultry	71
Body analyses of poultry and other animals	74
Bearing of present experiments on certain dietary studies	74
Some miscellaneous observations	77
The retention of food in the crop	77
Notes on the composition of the excrement	78
Summary	88
Bibliography	106

ILLUSTRATIONS.

	Page.
PLATE I. The collection pan, attached	32
II. The collection pan, attached, side view	32
III. The collection pan, with fastenings.....	32
IV. The collection pan, with fastenings, side view	32
CHART I. The digestion coefficients of the grain experiments.....	112
II. Average coefficients of all experiments.....	112

DIGESTION EXPERIMENTS WITH POULTRY.

PREFATORY.

INTRODUCTION.

The study of the digestion of feeding stuffs has not been extended equally to all classes of farm animals. The great bulk of the available data in this connection relates to ruminants, horses, and hogs, while but meager attention has been given to poultry. The practical importance of investigations designed to supply this deficiency is obvious. There has been a great increase in the poultry industry during recent years, with a growing demand for information regarding the care and management of the different kinds of domestic fowls. Feeding standards, based on the digestion coefficients of the various foodstuffs, have not been available, and poultrymen have especially felt the need of such as an aid toward attaining the most economic and productive methods in the nutrition of their stock. Many of the experiment stations have considered questions of poultry nutrition, and much of value has been accomplished. Aside from a single publication, however, these investigations have been limited to feeding experiments. Such observations are of value only as regards the particular diet under consideration and fail to afford the data necessary for the rational combination of a wide choice of nutrients. It is, therefore, very desirable that the digestion coefficients of a wide variety of poultry foods be made accessible under an extensive range of conditions. On such a basis feeding standards might be adopted which would prove a source of much economy. By the use of such standards much wastefulness caused by feeding new or untried feeding stuffs might be avoided and poultrymen would be enabled to incorporate into the diet only those materials which possess relatively the highest digestibility at relatively the lowest cost.

The published data at hand relating to digestion coefficients for poultry are insufficient in number and variety to justify the adoption of feeding standards or even to arrive at definite conclusions regarding the availability of the nutrients of the foods tested. This lack of literature on the digestive capacity of poultry is in marked contrast with the abundant data available for other classes of farm animals. The main reason for this seems to lie in certain difficulties of technique encountered in digestion experiments with poultry. This is obvious.

when some of the conspicuous differences in anatomical structure between birds and mammals are considered.

The anatomical structure of the bird is relatively much less complex than that of the mammal. The genito-urinary apparatus is notably simpler in structure. The urine is not temporarily stored in a bladder, as in mammals, but is conveyed directly from the kidneys through the ureters to the cloaca, there to be admixed with the fecal matter from the intestines. The structure of the alimentary canal of the bird suggests that the digestive process is rapid and that it partakes of features associated with both the carnivora and herbivora. Thus the relative shortness of length is a carnivorous characteristic, while the character of the diet and the thorough comminution of the food in the gizzard are features more akin to the herbivorous type.

The fact that the urine and feces are excreted together has formed the chief obstacle to progress in the performance of digestion experiments with poultry. As the accurate analysis of the fecal matter is essential for the estimation of the digestion coefficients, it is obvious that the matter is seriously complicated by this admixture with the urine; and, while the same general principles are applied in the study of the digestion coefficients of birds and mammals, certain modifications in the collection and analysis of the excrement are required in the case of the former, and peculiar difficulties are met with which have hindered advance in this direction. The analytical procedure in digestion experiments with poultry would be greatly simplified and accurate results more readily obtained if the mixture of the urine and feces could be avoided.

The plan of the introduction of cannulae into the ureters, thereby separating the urine in a pure condition, might be attempted, but does not seem feasible for quantitative operations. Two investigators, whose experiments will be reviewed later, have established an artificial anus in the abdominal wall. It seems doubtful, however, whether such operative procedure can be followed without interference with the health of the fowl.

The separate collection of the urine and feces is absolutely essential to the estimation of such constituents of the food as are eliminated in the urine either partially or wholly in unchanged form. Under these conditions the quantity of urine excreted in the feces could not be determined, and therefore the calculation of the quantity excreted by the intestines would be excluded. Both the feces and urine include inorganic matter, and consequently the balance of income and outgo of this material, so far as the alimentary tract is concerned, could not be estimated, and the digestion coefficient for inorganic matter could not be ascertained. It has been demonstrated^{1-4a} that certain pentoses may be eliminated through the kidneys of mammals unchanged,

^aThe figures refer to bibliography at end of bulletin.

at least in part. If such were the case with birds the estimation of the digestion coefficient for pentosans would be very difficult. To render this accurate a method for the mechanical separation of the urine and feces should be devised.

Another difficulty encountered in digestion experiments with poultry is that the fowls are less adaptable to the general conditions of such experiments than other farm animals. The body temperature of birds is considerably higher than that of mammals and their respiration is much more rapid. Owing to their energetic temperament they do not bear confinement as well as many other classes of animals, and therefore some depression of the normal metabolic activity may be involved.

The problem of a satisfactory collection of the excrement has also delayed progress in investigations of the present character, and this is peculiarly complicated when taken in connection with the study of egg production as connected with the digestibility of feeding stuffs. Under such circumstances a collection apparatus would not be feasible, and it would seem to be necessary to maintain a constant watch over the animals so as to remove the excrement immediately after it has been voided.

PURPOSE OF THE PRESENT PAPER.

The chief components of poultry rations are represented by the grains, of which corn, oats, and wheat are probably most commonly used. Corn especially, may be said to form the basis of most poultry-rations. It was planned to perform digestion experiments with each of these grains as the sole diet; also tests with a pure beef diet. Although these grains are commonly fed in combined rations, it seems to be of practical interest and value to determine their individual digestibility. In this way data may be acquired showing in what measure they form a balanced ration within themselves, or how they may be combined to the best advantage. It was also proposed to select a sufficient number of birds to determine, as far as possible, the factor of idiosyncrasy and unavoidable experimental error.

The present experiments are of a preliminary character only, and the number reported is insufficient to justify conclusions of a far-reaching character. This is doubly emphasized in view of the fact that so little investigation has been expended on the digestive processes of fowls. It is hoped that these experiments may serve as a starting point for a broad study of the availability of feeding stuffs for poultry, and it is believed that the experience gained in this investigation will be useful in future work.

CERTAIN FEATURES OF NITROGENOUS METABOLISM IN BIRDS.

DIFFERENCES BETWEEN THE NITROGENOUS END-PRODUCTS OF BIRDS AND MAMMALS.

There are several striking and significant points of difference between the urine of mammals and birds which must be taken into account, not

only in a study of nitrogenous metabolism, but also in a consideration of the digestibility of feeding stuffs in these classes of animals. A prominent peculiarity of avian urine is its relatively small content of water. This readily evaporates on standing in the open air, and the urine thus dried presents the familiar appearance of white flakes scattered irregularly throughout the fecal matter. Meissner⁵ observed many years ago that this white material, when examined under the microscope, presented the appearance of a mass of rounded amorphous particles, but when treated with a little acetic acid it immediately assumed a crystalline form and was apparently of uniform character. This substance is now known to be uric acid. The most important and prominent nitrogenous constituents of mammalian and avian urine are urea and uric acid, respectively. Broadly speaking, the quantitative proportions of these two substances are mutually reversed in the two excretions, that is, the urine of the bird contains only a very small fraction of urea and the proportion of uric acid to urea in the mammalian excretion is correspondingly small. Urea represents the great bulk of the excreted nitrogen of the mammal, while uric acid bears an analogous relation to the nitrogenous metabolism of birds. The uric acid of mammalian urine, however, does not owe its origin to the breakdown of proteid matter as such, but it is now believed to be largely derived through the metabolism of the nucleins. It is of suggestive interest that the high solubility of urea renders it particularly adaptable to the mammalian urine, which is of large volume, while uric acid, in view of its difficult solubility, is more suited to a urine of small water content.

The urine of birds differs strikingly from that of mammals in its comparative simplicity. Sir William Roberts⁶ comments on the matter as follows:

The chlorides, phosphates, and sulphates, the lime and magnesia salts, the pigment and large volume of water, all of which figure as prominent and even essential components of mammalian urine, are either wholly absent from the urine of birds and serpents or are only present in such minute traces as might be derived from the lubricating mucous and epithelial debris with which the secretion is incidentally mixed.

* * * But whereas in the urine of men and mammalia the quadriurates are only an insignificant item amid a host of other ingredients, the quadriurates constitute practically the whole of the renal excretion of birds and serpents. * * * The amorphous deposit is the physiological homologue of the entire renal activity of birds and serpents.

The above quotations are of a somewhat speculative nature, but in the main they express the general relations of the two types of animal excretions. In addition to uric acid and urea the urine of the bird may contain other substances in minute quantities. The exact comparative chemistry of the urinary output of birds and mammals has not been systematically investigated. The scanty literature on the

subject and a few observations of the writer in this connection are presented in another section of this paper.

THE PLACE OF FORMATION OF URIC ACID IN BIRDS.

It was early recognized that uric acid in the urine of birds possessed a significance akin to that of urea in mammals, namely, that this excretion embodied the form of the main nitrogenous end-product of proteid metabolism.

Much speculation has arisen relative to the mode and place of formation of uric acid in the organism of birds. In searching for an organ to which uric acid production might be delegated, physiologists early turned their attention to the kidney. Experiments were first performed on the hypothesis that the kidney is the sole seat of uric acid formation in the organism, and hence the removal of this organ would do away with uric acid production.

von Schröder⁷ succeeded in overcoming the great difficulties encountered in this work. In some of his experiments the kidney was merely excluded from the circulation, and uric acid was observed to accumulate readily in certain of the tissues and organs. Snakes,⁸ which, like birds, excrete the body nitrogen largely in the form of uric acid, lived from five to nine days after the removal of the kidneys, and deposits of uric acid or urates were found in several of the organs. These observations indicated that the kidney was, at least, not exclusively concerned in uric acid formation. This evidence is further sustained in the consideration of the comparative structure of the kidney in birds and mammals. A further statement of Sir William Roberts is of interest in this connection:

It is remarkable that the wide differences in the nature of the renal excretion in mammals and the sauropsida, respectively, should yet be associated with almost complete identity in the anatomical structure of the kidney. The kidney of the bird has a glomerular mechanism identical with that of the mammalian organ, * * * and yet practically the sole function of the organ of the bird, in contrast with the remarkably complex duties performed by that of the mammal, is to secrete quadriurates.

In view of this common structure of the kidney in the two classes of animals, it would hardly appear consistent that the organ should form large quantities of uric acid in the one case and relatively minute amounts in the other.

The preponderance of evidence so far accumulated has indicated that the place of urea formation in mammals is the liver. Minkowski⁹ endeavored to ascertain whether uric acid in birds—the physiological homologue of urea in mammals—is synthesized in that organ. In order to investigate whether an interrelation exists between uric acid production and the activity of the liver, he studied the influence of the removal of the liver on the composition of the urine. The difficulties

met with in mammals in the attempt to withdraw the liver from the circulation do not occur in birds, and it is not necessary to guard against the congested condition which occurs in mammals by establishing artificial communication with the ascending vena cava. In the case of birds, such a communication has a natural existence, as these animals have a vascular system in the kidney similar to the portal circulation in the liver. Taking advantage of this fact, Minkowski¹⁰ extirpated the liver from geese. In some cases the organ was merely cut off from the circulation. The large intestine was ligatured immediately above the cloaca in order to obtain the urine in a pure condition. The results of this experiment were so striking as to afford strong evidence that the liver was concerned with at least a part of the uric acid production in birds. The uric acid output, as a result of the operation, suffered a tremendous decrease. While the uric acid nitrogen normally corresponds to from 60 to 70 per cent of the total urinary nitrogen, under these conditions the percentage fell to from 3 to 6. This conspicuous reduction of uric acid nitrogen was largely replaced by a corresponding increase in the output of nitrogen in the form of ammonia. Prior to the operation the ammonia nitrogen comprised from 9 to 18 per cent of the total nitrogen of the urine, but subsequent to the removal of the liver this fraction reached from 50 to 60 per cent. Another very significant result was that this increased ammonia was present in the form of a salt of lactic acid, a substance which Minkowski was unable to detect in the normal urine. In these results he saw evidence that ammonia and lactic acid were produced by the oxidation of the proteid matter in the tissues, and that a synthesis of these two substances to uric acid was accomplished in the liver.

The findings of Minkowski's experiments have recently been fully corroborated by the observations of Lang.¹¹ Employing a slight modification of the operative procedure of Minkowski, he differentiated the urinary nitrogen into three fractions, namely, (1) ammonia, (2) uric acid and purin bases, (3) urea and creatin, assuming that the last-named body is present in the urine. The percentage of fall in uric acid elimination after the operation corresponded essentially to the results reported by Minkowski. Data are also recorded in this paper relative to the percentage of distribution of the above-named fractions of nitrogen relative to the total nitrogen in the normal urine of geese.

A recent communication by Kowalewski and Salaskin¹² lends support to the conclusions of Minkowski and Lang. Their experiments show that the liver takes a direct share in the formation of uric acid in birds. Not only ammonium lactate and ammonium salts of other organic acids, but such substances as arginine gave rise to its chemico-physiological production.

We find no investigation on record which has considered the

possible relation between uric acid formation and the activity of the spleen in birds. It was long thought that variations in the volume of the spleen were associated with fluctuations in the uric acid excretion in mammals, but later researches have proved that the spleen has no essential influence on the production of this excretion.

Mendel and Jackson¹³ estimated the uric acid output before and after extirpation of the spleen in dogs and cats. A comparable diet was fed during both periods. The daily excretion of uric acid remained practically unchanged after the operation. Noël Paton¹⁴ investigated the effect of splenectomy on the nitrogenous metabolism of dogs and found that practically no deviation from the normal appeared. Lo Monaco¹⁵ observed that the excretion of uric acid remained unaltered after extirpation of the spleen in man. These observations make it appear improbable that the spleen in birds bears an essential relation to uric acid formation.

It has been demonstrated that a small portion of the excreted uric acid of birds is formed independently of the liver. Thus Minkowski¹⁰ and Lang¹¹ found a small residuum of that substance in the urine after extirpation of this organ. It has been suggested—and there is some experimental evidence to support this view—that this fraction of the uric acid is formed under conditions similar to those obtaining in mammals. In the latter class of animals uric acid production is now regarded as sustaining an intimate relation to the character of the diet. It has been established during the last ten years that those organs of the body which are rich in cell nuclein—such as glands of the type of thymus, liver, spleen, etc.—occasion a marked rise in the elimination of uric acid when fed as a part or the whole of the daily diet. This rise in uric acid excretion is referable to the nuclein material which makes up the bulk of the cell nuclei. It has been shown that the nucleins when decomposed by boiling mineral acids yield xanthin bases—bodies closely related in structure to uric acid. The xanthin bases are regarded as direct precursors of uric acid formation. Abundant observation has proven that food materials free from nuclein are practically without effect on the uric acid output in mammals. Variations in the amounts of uric acid excreted are attributed to fluctuations in the amount and character of the nuclein of the food and also fluctuations in the extent of the metabolism of body nucleins.

The question whether or not a fraction of the uric acid in the bird is referable to this mode of formation naturally suggests itself. von Mach¹⁶ has pointed out that the administration of hypoxanthin to geese deprived of the liver strikingly increased the elimination of the residuum of uric acid. This result is in harmony with the observations reported by Minkowski,¹⁷ Burian and Schur¹⁸ and Krüger and Schmid,¹⁹ all of whom noted a similar result with man. Milroy²⁰ has recently

shown that the ingestion of pure nucleins may lead to an augmented uric acid output in hens. The chickens selected for the experiments were operated upon for an artificial anus in order that the urine and feces might be separately excreted. These observations thus give evidence that a small portion of the uric acid of birds may be formed from precursors which give rise to an increased elimination of this excretive in mammals and also that some uric acid may be formed independently of hepatic activity. Variations in uric acid excretion in birds probably depend on two main factors—(1) the quantity of proteid and (2) the amount of nuclein contained in the food. The details of the exact relations of these two factors to uric acid production are yet to be determined.

The various facts cited above indicate that uric acid in birds is largely formed synthetically, while in man it results mainly from oxidation processes. Wiener's²¹ investigations suggest that uric acid may be to some extent formed synthetically in the liver of the ox. He found, however, that extracts of the kidney of the ox and the horse destroyed uric acid, while extracts of the liver of dogs and pigs produced a similar result. How far these observations would apply to the organs of birds can only be answered by experiment, but they tend to show that in the case of mammals the quantity of excreted uric acid is not necessarily an indication of the total amount formed in the body.

The circumstances pertaining to the formation of the small amount of urea in the urine of birds are entirely unknown. Minkowski¹⁰ estimated that this substance represented about 4 per cent of the total urinary nitrogen. It is significant that he found this proportion unaltered after extirpating the liver. This result affords evidence that urea is at least not entirely formed in the liver in birds, although its synthesis in the liver of mammals seems to be established.

THE ANTECEDENTS OF URIC ACID PRODUCTION.

The mode of formation of uric acid in birds has been an object of research with several investigators. As urea appeared to be a possible further physiological oxidation product of uric acid, it was early suggested that uric acid in birds might be derived from the same metabolic antecedents as urea in mammals.

Schultzen and Nencki²² observed that when leucin and glycocoll were administered to dogs they were eliminated as urea. Salkowski²³ confirmed these results, and von Knieriem²⁴ found that aspartic acid was transformed into urea in the same animals. The influence of ammonia salts on the output of urea in dogs and men has been considered by von Knieriem, and Salkowski studied the same question with reference to dogs and rabbits. Ammonium chloride was largely transformed into urea in the case of rabbits, while in the case of dogs and men the greater part of the salt was excreted in the same form

as ingested. The carbonate of ammonia was entirely transformed into urea in the organism of the three types of subjects. Feder and Voit²⁵ found that the acetate of ammonia led to the excretion of urea, while Lohrer²⁶ made the same observation with reference to the citrate salt.

Several observers^{27, 28} have reported experiments planned to study the relation of certain of the above-mentioned ammonium salts to uric acid formation in birds. Schröder²⁹ reported that the ammonium salts of acetic and formic acids were readily excreted in the altered form of uric acid. The chloride and sulphates, however, were removed by the kidneys unchanged, a fact which may account for the proportionately greater amount of ammonia that is normally excreted by the bird as contrasted with the mammal. Meyer and Jaffé²⁷ have individually reported that urea when administered to birds is eliminated as uric acid. Meyer claimed that part of the urea nitrogen appeared in the urine as ammonia salts. He found that the ingestion of uric acid led to its excretion in unchanged form with a slight rise in the body metabolism, while it has been shown that in the organism of mammals uric acid is more or less completely converted into urea. von Knieriem observed that amido acids, as leucin and tyrosin, increased the uric acid output in birds, while we have seen above that these bodies are precursors of urea in mammals.

When the data of these parallel experiments with birds and mammals are correlated, the following statement of Hopkins³⁰ is of suggestive interest:

The physiological differentiation whereby soluble urea takes the place of insoluble uric acid in accordance with the needs of an organism excreting a liquid urine is now known to occur at the final stages of metabolism. It is almost certain that in the main the waste products which leave the tissues are the same in birds and mammals. In the liver of the former these products are prepared for excretion by a change into the form of uric acid, while in the latter the hepatic influence produces urea.

A further characteristic difference in the nitrogenous metabolism of mammals and birds is brought out by a consideration of the comparative behavior of benzoyl compounds in the organism of these two classes of animals. It has long been known that the ingestion of salts of benzoic acid calls forth an increased output of hippuric acid in mammals. It is thus apparent that a synthesis of glycocoll and benzoyl compounds occurs somewhere in the body, and it is a fact of much interest that Bunge and Schmiedeberg³¹ were enabled to demonstrate that this process was carried out, at least in part, in the kidneys. When benzoyl compounds are administered to birds, the resulting excretion is quite different from that observed in the case of mammals. Jaffé³² observed that the condensation product of diamidovalerianic acid and benzoic acid is excreted—a compound known as ornithuric acid and analogous in structure to hippuric acid. The locality of formation of this homologue of hippuric acid has not been investigated,

but it appears not improbable that by analogy it is formed synthetically in the kidney.

The metabolism of sulphur in birds has been studied by Lang.³³ He investigated the effect of removal of the liver on the relationships of various forms of sulphur in the urine. The results were practically of a negative character, and he concluded that the liver plays no essential rôle in the elaboration of sulphur compounds in the form in which they appear in the urine.

REVIEW OF LITERATURE ON DIGESTIVE SECRETIONS OF BIRDS.

In accord with the lower evolutionary position of birds as contrasted with mammals, we find the structure of the digestive viscera in the former class of animals much less complex than in the latter. Comment has already been made on the simpler trend of nitrogenous metabolism in birds, and the less highly developed organization of the genito-urinary apparatus. The absence of mastication, the storage of food in the crop, and the peculiar muscular gizzard are all salient features characteristic of the digestive apparatus of the bird. The intestines fail to show the well-defined subdivisions so conspicuous in the mammalian organ. The caliber of this portion of the alimentary canal shows but little variation except at about the last inch of its length, where it widens before terminating at the cloaca. A peculiar feature of the intestines is the marked bilateral development of the cecum, which attains considerable length and joins the intestine a short distance above the cloaca. The writer has repeatedly observed in autopsies that the folds of mucous membrane or valvulae conniventes are especially conspicuous in this portion of the alimentary tract, thus indicating that a considerable share of the absorption of digestive products may take place in the ceca. In view of the anatomical considerations referred to above, it is suggested that the digestive changes of the foodstuffs may be of a simpler character than those noted in mammals.

THE CROP, ESOPHAGUS, PROVENTRICULUS, AND GIZZARD.

The function and structure of the crop have been considered by several investigators. Teichmann³⁴ reports that the mucous glands situated in the deeper portion of the mucous membrane are the only glandular structures present; no evidence was afforded that the crop secreted any digestive fluid. Klug³⁵ has reported that he found traces of acid and pepsin in the organ, derived from the stomach, and a part of the acid reaction may possibly also be accounted for by food fermentation. The purpose of the crop is to soften the food both by means of mucus carried down from the mouth and the secretion of the mucous glands of the organ itself. In 1786, Hunter³⁶ described the so-called "crop milk" of pigeons, and Hasse³⁷ in 1865 further dis-

cussed the same matter. This body fluid is often secreted by the crop of pigeons at breeding time and is furnished to the newly hatched birds. It is largely composed of mucous and cast-off epithelial cells.

Teichmann³⁴ also investigated the histological structure of the esophagus, proventriculus, and gizzard. The proventriculus appears as a dilation of the esophagus located at a short distance above the gizzard. The function of this organ seems to be to secrete pepsin and hydrochloric acid to be admixed with the food preparatory to the grinding of the material in the "muscular stomach," or gizzard. Broadly speaking, an analogy may be drawn between the cardiac, or main secretory portion of the stomach in man, and the proventriculus in birds; also between the more muscular, or pyloric, portion in the human organ and the gizzard of the bird.

THE GASTRIC JUICE.

By the use of an ingenious method, Réaumur³⁸ first obtained gastric juice from birds. Lead tubes containing sponges were introduced into the alimentary tract of certain birds of prey. The entrance of foreign indigestible bodies into the alimentary tract causes these animals to vomit. When the tubes were ejected, considerable fluid could be squeezed out of the sponges contained therein. As these experiments were performed some years prior to Schwann's discovery of pepsin, the observations were limited to the salty and bitter taste, the acid reaction toward litmus, and the softening and slightly solvent action of the secretion on meat. Réaumur also studied the action of the gastric juice by introducing into the stomach food materials inclosed in cylinders open at one end. He found that little solvent action resulted unless the food in question was subjected to the grinding action of the gizzard.

The observations of Réaumur were considerably extended by Spallanzani³⁹. Meat was shown to be completely dissolved in the gizzard of herbivorous birds, even when protected from the movements of the walls of the organ by inclosure in glass cylinders. The action of gastric juice collected by sponges as performed by Réaumur was studied outside of the body. Cheese, meat, bread, etc., were found to be almost completely dissolved. Those birds which possessed little mechanical power in the stomach secreted a notably active gastric juice. The action of this secretion was studied in a large variety of birds, as the vulture, owl, hawk, eagle, etc.

Tiedemann and Gmelin⁴⁰ collected gastric juice according to the method of the investigators heretofore named. They found that it always gave an acid reaction, and, in addition to the solvent effects described by Spallanzani, it clotted milk. The acid of the gastric secretion is described by these workers as hydrochloric, and they claim to have obtained evidence, in some cases, of the presence of acetic and

even nitric acid, which, if substantiated by further inquiry, is of curious interest, as these two acids have never been reported in the normal gastric juice of mammals. These observers noted that the strength and amount of the secreted acid depended on the nature of the food material ingested. Irritating substances, such as pepper, brought forth the largest amount of acid, and the gastric juice secreted after a diet of meat reacted more strongly acid to litmus than the secretion following the use of liquid food and sugar.

Wilczewski⁴¹, in 1870, at Heidenhain's institute, performed some experiments with the pepsin of the pigeon's stomach. Extracts of the mucous membrane were made with 0.2 per cent HCl, and the digestion of egg albumin in these fluids was tested. A control trial was carried out with 0.2 per cent HCl alone and more albumin was dissolved by this solution than in the extract which presumably contained the peptic enzyme. Obviously, some error was involved in the performance of these experiments.

In 1890 Klug³⁵ published a communication dealing with the digestion processes in geese. He was unable to demonstrate an acid peptic secretion in the crop or esophagus. Traces, which might have regurgitated from either the fore stomach or gizzard, were sometimes found in these localities. Extracts of the latter organ, made with 0.2 per cent HCl, readily dissolved proteid substances.

On the authority of Teichmann,³⁴ the glands in the proventriculus were found to be of compound tubular structure and resembled mammalian gastric glands. The secreting portion of the gland is described as containing but one variety of cell elaborating both pepsin and hydrochloric acid; in mammals the acid is probably secreted by a type of cell distinct from that producing the enzyme.

The muscular stomach or gizzard presents a peculiar structure. On a more or less strongly developed muscular foundation is found a layer of tubular glands which manufacture a secretion, the character of which has not been determined. The topmost layer of the mucous membrane is made up of a horn-like mass of stratified squamous epithelium. A complete list of the literature bearing on the histology of the gastric apparatus of the bird, published prior to 1896, is given by Oppel.^a

The most recent and extensive contribution to the literature on the digestive processes in birds was published by Paira-Mall⁴² in 1900. The main conclusions of this paper may be stated as follows: In granivorous birds the gland cells of the mucous membrane of the proventriculus are laden with peptic enzyme or zymogen in the fasting period. The ferment appears to be stored up in the form of granules, which are discharged from the cells rather quickly during digestion, so that

^a Lehrbuch der vergl. mikrosk. Anatomie der Wirbelthiere, Erster Theil: Der Magen, s. 150 ff., Jena, 1896.

the mucous membrane contains much less ferment during the first few hours of this process than in the fasting period. As has been established for mammals, the zymogen develops into the full-fledged enzyme by the action of the free hydrochloric acid secreted by the gland cells. The mucous membrane seems to yield the minimum amount of ferment six to eight hours after the ingestion of the meal, simultaneously with the height of digestive activity. At the tenth to eleventh hour after taking food, the quantity of enzyme commences to gradually increase.

The "muscular stomach" or gizzard secretes no pepsin, and the evidences of the enzyme found in this organ are to be attributed to the secretion of the proventriculus. As reported by Klug and Teichmann, no peptic secretion could be demonstrated in the crop or esophagus. Mucus and in some instances "crop milk" were the only secretions noted. Gastric digestion in birds possessing a so-called middle stomach—as the crow, magpie, etc.—was investigated and results were obtained corresponding to those noted in the granivorous birds.

THE PANCREATIC JUICE.

There is but scant literature bearing on pancreatic digestion in birds available. Claude Bernard,⁴³ in 1856, first pointed out the great vital significance of the pancreas in birds. He removed the organ and observed that, while the subjects endured the operation well, starch passed through the gastro-intestinal tract undigested and death resulted in from ten to twelve days. It is of interest in this connection to note that the total removal of the pancreas in mammals leads to the production of a fatal diabetes. Whether this effect ensues in birds under like conditions can only be answered by experimental inquiry. This factor, however, may have been operative in the fatal results induced by Bernard's experiments.

The effect of ligature of the pancreatic ducts in pigeons has been studied by Langendorff.⁴⁴ The gland in this class of birds possesses from two to four ducts. The results obtained were essentially the same as those reported by Bernard after total removal of the organ. The animals suffered from severe hunger and survived but a few days. The carbohydrate component of the diet was practically unassimilated; the proteid and fat but slightly. It was noted, as would be reasonably anticipated, that the life of the pigeon could be considerably prolonged by administering large amounts of soluble sugar.

Langendorff carried out observations on the digestive enzymes of the pancreatic juice. The ferments were not separated, but he reports that the starch and fat-digesting power of the secretion were relatively more active than the proteolytic. Klug³⁵ extracted the pancreatic enzymes of the goose and states that proteid and starch were readily digested; the fat-splitting enzyme appeared to be present in a relatively

very small amount; but the presence of a rennet or milk-curdling enzyme could not be demonstrated.

It may be well at this place to point out that the pancreas of the bird is very large in relation to body weight as compared with that of the mammal. In the rabbit the weight of this organ is about one six-hundredth of the body weight, while Langendorff has estimated that in the pigeon this gland is from an eighty-second to a hundred and twenty-fifth of the total weight.

Pancreatic digestion was investigated by Paira-Mall⁴² in both granivorous birds and those possessing the "middle stomach." The histological changes associated with the elaboration and discharge of ferment in the pancreas were very similar to those described by Heidenhain⁴³ in the dog under like circumstances. The gland cells in the fasting period contained little proteolytic and amylolytic ferment, but simultaneously with the onset of gastric digestion the cells became crowded with the zymogen granules. Paira-Mall makes no reference to the presence of a rennet-like enzyme in either the stomach or pancreas, and no attempt was made to demonstrate the existence of enzymes in the intestinal wall.

This brief review of the literature indicates that there is an urgent need for investigation of the digestion processes in birds. This is not only of scientific interest from the standpoint of comparative physiology, but of practical significance as an aid in the interpretation of the data of digestion experiments. The detailed chemical changes brought about by the ferments upon the different classes of food-stuffs, and hence the determination of the final products of digestive activity, are yet to be investigated. A more exact study of the distribution of the enzymes in the gastro-intestinal tract and the effects of varying conditions upon their activity furnish promising objects of investigation.

REVIEW OF THE LITERATURE ON THE DIGESTIBILITY OF POULTRY FOODSTUFFS.

The earliest publication⁴⁶ bearing on the digestion coefficients of the nutrients of feeding stuffs for poultry appeared in 1843. The digestion of barley in a cock and hen were studied, chalk and sand being offered with the grain. The chickens excreted a little less than one-half of what they consumed, and the excrement consisted of, approximately, 25 per cent of inorganic matter.

Voit,⁴⁷ in 1861-62, determined the nitrogen balance in a dove, employing a period of observation of one hundred and twenty-five days. This experiment, while not a digestion test, is worthy of mention in this connection, as it demonstrated the absence of a respiratory exchange of nitrogen.

Weiske and Mehliis,⁴⁸ in 1877, investigated the digestibility of crude

fiber in hens. The food consisted of the leaves of the dandelion and stalks of the horsetail rush. They came to the conclusion that crude fiber was not assimilated.

Observations on the digestibility of millet in hens were reported by Kalugin⁴⁹ in 1897. He asserted that the addition of sand or charcoal to the food increased the digestibility of the nutritive ingredients, especially in the case of crude fiber and crude protein. The percentages of increase in absorption of these nutrients for two experiments were in one subject 4.58 and 2.33 and in another 7.73 and 7.89, respectively.

In another publication⁵⁰ he records data with reference to the digestibility of peas, buckwheat, wheat, and barley in hens. The following conclusions were drawn: Hens digest the crude proteid of peas and barley in about the same proportions as has been observed in experiments with other farm animals; the assimilation of the crude proteid of wheat and buckwheat was much inferior to that found in the other two grains. In their capacity to utilize fat, fowls in some respects resemble swine and in other respects, herbivora.

Grost investigated the individual digestibility of oats, barley, and rye at the Peterhof experimental farm in 1900. The experiments were performed under the direction of von Knieriem.⁵¹ In the experimental period proper 70 grams of the grain in use were fed once daily. The most noticeable feature of the experiments was the low availability of the fat of rye as compared with oats and barley. This finding was in harmony with results obtained in digestion experiments with rye carried out with pigs, cows, and sheep. The digestion coefficient of fat in oats was considerably higher than in the case of barley. Crude proteid was found to be digested in higher proportion in rye and barley than in oats. The crude fiber of barley and oats was absorbed to a slight extent; considerably more of this constituent was assimilated in the case of rye.

In Bulletin No. 46 of the Oklahoma experiment station Fields and Ford⁵² record experiments designed to study in poultry the digestibility of Kafir corn, Indian corn, and cowpeas. Certain features of the conduct of these experiments are open to criticism and will be discussed later (see p. 61). The deductions drawn from the tests were as follows: The digestion coefficients of Kafir corn and Indian corn are rather higher when the grain is fed whole than after its ingestion in the form of meal. The reverse of this was the case with cowpeas, although the differences were not marked. The percentage of digested crude proteid, ether extract, and nitrogen-free extract was generally higher in both Kafir and Indian corn than in cowpeas.

Lehmann⁵³ recently performed two digestion experiments with hens, wheat and peas being the grains studied. The outlets of the urine and feces were separated by means of an artificial anus established in the

abdominal wall. The practical value of the data obtained in experiments where such an operative procedure is employed may be somewhat questioned, owing to the possibility that the digestive processes may be abnormally influenced. The general results of the experiments were as follows: The assimilation of the crude fat of wheat was much less than was observed in the case of peas. On the other hand, the digestion coefficient for crude proteid in peas was considerably the greater. The reverse relation held true for the nitrogen-free extract. Lehmann concluded that the digestion coefficients for poultry are more comparable to those of swine than to those of other farm animals.

Shortly before the completion of the writers' experiments a publication on this subject appeared from the Berlin Hochschule. The experiments were performed by Paraschtschuk⁵⁴ and deal with the digestibility of corn in hens and cocks. As in Lehmann's experiments, an artificial anus was established in order that the urine and feces might be separately collected. He reports that the only untoward sequence of the operation was a condition of constipation, which necessitated frequent flushing of the intestines with physiological salt solution in order to effect defecation. The normal condition of the feces, however, was soon restored. The inferences drawn from these experiments are as follows: The digestive capacity of poultry does not depart widely from that of the large farm animals. In their ability to assimilate crude fiber they resemble swine more than ruminants and horses. The digestion coefficient for ether extract corresponds most closely to that of ruminants. Poultry assimilate nitrogen-free extract in less degree than any of the other three classes of animals.

The digestion coefficients comprised in the five papers just referred to are presented in Table IX on page 99, the digestibility of corn, oats, wheat, barley, peas, rye, and buckwheat having been considered. Data on three grains only—corn, peas, and barley—have been reported by more than one experimenter. A casual comparison of these data shows that, with the exception of the digestion coefficients of barley, the results of the different experiments are more or less lacking in agreement. These discrepancies may be accounted for in various ways, as differences in analytical methods, in the length of experimental periods, and in the manner of collection and preservation of the excrement. The factor of idiosyncrasy might also act as a cause of variation. A more detailed consideration of these data will be given at another place in connection with the discussion of the results of the writer's experiments.

MEAT AS A SOLE DIET FOR POULTRY.

Experiments planned to study the digestibility of meat have not as yet been undertaken with poultry. Meissner,⁵ Minkowski,¹⁷ Meyer.⁵⁵

and Kionka⁵⁶ have fed meat to birds experimentally, but not with a view to the determination of digestion coefficients. Meyer and Kionka investigated the nitrogenous metabolism after meat feeding. Kionka confirmed an observation of the other investigators named in finding the uric acid output enormously increased after a heavy meat diet. He found a rise of 550 per cent over that excreted following an exclusive diet of barley. The excrement from meat feeding showed an enormous content of water as compared with the grain excrement.

It is of interest in this connection to refer to a pathological condition noted by Kionka as a result of this exclusive meat feeding. Each subject received large quantities of beef (150 grams daily) over varying periods of many weeks in length, and was kept in close confinement. This diet was responsible for the production of symptoms simulating in a striking manner the condition of gout in man. The autopsies revealed deposits of uric acid in certain of the joints and tissues. These results are of special interest when associated with the fact that the addition of meat to an ordinary diet occasions a pronounced increase in the elimination of uric acid in man. This effect may be attributed to the content of purin bases in this form of diet, and this fact may bear a causal relation to the results noted above in hens. The findings of these experiments are instructive as suggesting the possible injurious effects of feeding meat to poultry, either exclusively or in an unduly large proportion in a mixed ration. The tendency to harmful results in the above experiments would no doubt have been greatly lessened if the animals had been given unlimited opportunity for exercise in the open air.

Kionka also studied the influence of the feeding of lime on the nitrogenous metabolism. The animals consumed 150 grams of meat daily, to which were added 10 grams of egg shells—which consist largely of calcium carbonate. The results were strikingly significant. The water of the excrement was enormously increased, while the dry matter remained practically unchanged. On the other hand, while the total output of nitrogen showed little change, the uric acid excretion was reduced nearly one-half as compared with the results on the same diet without the inclusion of lime. This fall in the uric acid output tends to indicate a decrease in the assimilation of proteid, a suggestion which the microscopic examination of the excrement confirmed. In other words, the addition of large amounts of lime to the food would seem to depress the digestibility of proteid matter. While this statement may not be taken as conclusive, it suggests the possible harmful effects of feeding lime to poultry in undue proportion.

THE GLYCOGEN FORMATION IN BIRDS.

Closely associated with the digestibility of foodstuffs in poultry is the question of the glycogenic function of the liver. While the main

features of the process are probably identical in both birds and mammals, there may be minor differences of significance. It seems desirable to briefly mention the few observations recorded on the subject.

Tscherinow⁵⁷ first investigated the conditions of glycogen formation in birds in 1869. He observed that the glycogen disappeared very rapidly from the liver of fowls deprived of food, and the organ became practically glycogen-free in three to four days. Prausnitz⁵⁸ in 1890 investigated the question and came to the following conclusions: A starvation period of four days sufficed to render the liver free from any appreciable quantity of glycogen. Following the administering of cane sugar, the liver glycogen rose rapidly, reaching its maximum from the twelfth to the twenty-fourth hour. The value then fell rapidly, and at the thirty-sixth hour the liver was again practically glycogen-free. When the liver had attained a certain content of glycogen certain of the other organs and tissues of the body commenced to show an increased accumulation of this carbohydrate. This fraction of the body-glycogen increase was considerably greater after the eighth hour than that observed in the liver, and the maximum was reached at about the twentieth hour. The body-glycogen fell rapidly at first but later more slowly, and the minimum was reached at about the forty-eighth hour.

Hergenhahn⁵⁹ has also investigated several questions connected with the course of the formation of glycogen in the liver and muscles. Six-day starvation periods were imposed on the animals to render the liver glycogen-free. In three series of experiments the influence of 10, 20, and 30 grams of saccharose, respectively, on the glycogen formation in both liver and muscle was considered. The liver glycogen rose rapidly after the administration of the sugar, but the increase of the glycogen in the muscles was very gradual, appearing from twelve to sixteen hours later. It was noted that the liver glycogen practically equaled the content in the muscles in the sixth hour following the meal. The maximum of muscle glycogen appeared to be practically independent of the quantity of sugar ingested, and appeared in from twenty to twenty-four hours. Among many other observations it was reported that the smaller the quantity of sugar fed the more rapidly was the level of glycogen production in the liver reached.

ROUTINE AND METHODS OF PRESENT EXPERIMENTS.

The general plan of the experiments of this investigation is indicated in Table I (see p. 89). Nine hens (A, B, C, D, E, F, H, M, and N) and one cock (G) were employed as subjects and sixteen digestion trials were made. Additional experiments with other animals were also undertaken, but owing to derangement of digestion or other abnormal conditions arising these were abandoned. Chickens of varying weight were selected and were kept under observation for

not less than two weeks before any digestion tests were begun. During this time they were carefully watched in order to ascertain whether normal conditions prevailed. The digestion experiment proper was preceded by a preliminary period during which the experimental diet was fed. This preliminary period was never shorter than five days and served the following ends: (1) To accustom the fowls to the experimental diet; (2) to obtain data relative to the average daily voluntary consumption of the diet; (3) to eliminate from the alimentary canal residues from previous feeding.

During the preliminary period of the experiments the fowls were fed *ad libitum*, and so allowed to fix their own daily consumption of food. In the greater number of the experiments the daily ration offered during the digestion period corresponded to the average daily requirement observed in the preliminary period. In a few cases they received a quantity somewhat less than this in order that entire and absolutely uniform consumption of the ration might be secured. It was thought, however, that the conditions would conform more closely to those obtaining on the farm if the fowls were fed sufficient grain to entirely satisfy the daily appetite, even at the expense of some irregularity of food ingestion. It was also deemed unwise to extend the preliminary period over a longer time than was necessary for the objects above considered, as the more prolonged the use of a single article of food the greater the tendency to loss of appetite due to its monotony. The digestion periods proper of the experiments varied from six to thirteen days.

In the case of the meat experiments it was particularly needful to insure the entire and immediate ingestion of the meat fed. Unconsumed meat in the cage pan would soon tend to decompose, and owing to the large loss of water difficulty would be met with in accurately weighing any portions left over from the day's ration.

A common source of error in digestion experiments is involved in the irregular ingestion of food and excretion of feces. The periods of the present experiments seem of sufficient length to counterbalance the effect of such fluctuations. It has already been pointed out that the experimental conditions imposed on the animals tend to lead to depressing effects, and particularly in the case of subjects of so active a temperament as poultry. For this reason it is desirable that digestion trials should be performed with animals which have not been subjected to a longer confinement than is absolutely required.

The chickens for the experiments were kept in wire-netting cages 29 inches long, 17 inches wide, and 23 inches in height. The bottom of each cage was fitted with a galvanized iron tray, which could be easily removed and cleaned. The grain was offered in feeding boxes constructed of tinned iron fastened at the sides of the cages. These boxes were provided with a sloping bottom designed to allow the food

to slide to a lip which projected into the cage and was of such size as to permit of the fowls feeding without scattering the grain to any great extent. As a further precaution against loss of food cloth was fastened around the lower interior part of the cage. This arrangement prevented a loss of grain through the wire meshes of the cage and confined in the cage tray all of the food not immediately consumed. Feeding boxes of similar construction to the above were also employed for sand.

MANAGEMENT OF THE CHICKENS.

The chickens were carefully weighed each day in both the preliminary and digestion periods. This observation was made immediately after the removal of the collection pan and just before the feeding of the morning ration. The afternoon meal was given concurrently with the removal of the collection pan. The condition of the fresh excrement was carefully watched both morning and afternoon, its odor, consistency, and general appearance being noted. The appearance of the comb, condition of the appetite, relative loss of feathers, general bodily tone, etc., were given constant attention as possibly affording evidences of malnutrition. At any indication of a deviation from normal conditions the experiment was promptly abandoned.

The grain selected for the experiments was repeatedly winnowed and then carefully examined by hand in order that a lot as clean and uniform as possible could be employed. After sampling for analysis the grain was stored in air-tight cans and a little chloroform added to exclude any formation of molds. The preparation and sampling of the beef fed is described on pages 29 and 30. Feeding was always conducted at exactly the same time each day in each experiment. In some instances the chickens were fed once a day—in the morning—in others both in the morning and late afternoon. At the end of the daily period the grain remaining over was carefully collected and weighed. Water was supplied in circular glass dishes about an inch in depth, which were firmly fastened to the sides of the cages. The balance left over from each day's quota was measured, and the loss by evaporation checked by observing the change in volume in a control dish placed outside of the cage for a comparable period of time.

Gravel was offered in many of the experiments, and in such cases was given *ad libitum*. It was prepared in the following manner: Quartz rock was crushed in an iron mortar and the material passed through sieves with meshes of varying size until a quantity was obtained, the individual particles of which were fairly uniform, measuring roughly one-eighth of an inch in diameter. This mass of material was repeatedly treated with boiling dilute hydrochloric acid to remove any admixed traces of iron derived from the mortar or other soluble inorganic matter. The sand was widely scattered by the

animals on the trays of the cages, and much care was necessary to recover the same. The daily consumption was not determined, but the total ingestion for the experimental period was observed in several instances.

The advisability of supplying the chickens with marble was considered. Much difficulty lies in the way of an accurate determination of the consumption of gravel and marble when both of these materials are placed at the disposal of the animals. They become scattered together upon the bottom of the cage, and it is very difficult to distinguish accurately between the marble and quartz particles. In a few cases, as will be indicated later, a mixture of sand and marble was fed, but no account was taken of the amount of each consumed.

THE APPARATUS FOR COLLECTION OF THE EXCREMENT.

Methods of collecting the excrement adopted by certain observers are open to much criticism. Thus, Grost⁵¹ placed the subjects in a box-like structure which necessitated a stationary position throughout the period of the experiment. Kalugin⁴⁹ employed a similar method. Such close confinement of animals of so pronounced a vitality seems abnormal, and rather liable to lead to results deviating from the physiological. In the experiments of Fields and Ford⁵² the fowls were allowed considerable exercise, but the excrement was allowed to drop upon the tray of the cage and to a certain extent dry there before removal. Under these circumstances there is opportunity for a considerable loss of ammonia and progressive decomposition of the excrementitious matter. Paraschtschuk⁵⁵ used an ingenious method in the collection of urine and feces from his animals, upon which the operation for artificial anus had been performed. A small rubber bag was fastened about the artificial anus to receive the feces. This was inclosed by a larger rubber bag fitted about the rear portion of the animal, to serve as a receptacle for the urine.

After considerable study, the writer adopted the following method of collecting the excrement as the most feasible for the grain experiments. A device, made of aluminum and somewhat resembling a bed-pan in shape, was constructed. It was arranged to fit the rear portion of the fowl, and was provided with an opening which could be fitted tightly about the cloaca. This collection pan was fastened to the chicken by strips of aluminum, which were riveted to the sides of the upper third of the pan and met by their free ends in front of the wings, where they were securely fastened together by means of stout cloth tape. This arrangement was reenforced by strips of cloth tape, passing from lugs attached to the upper part of the pan and tied together in front of the wings. Plates I to IV show the collection pan and its appearance when adjusted.

The fowls evinced violent irritation after the attachment of the collection pan. The appetite was greatly reduced, little excrement was passed, and a partial loss of equilibrium ensued. Several days usually elapsed before normal conditions were restored, and the fowl ceased to show a disposition to remove the device. Even after the fowls had become thoroughly habituated to its employment, some irritation was usually shown during the attachment and removal of the apparatus. The pan was fastened to the chicken in the preliminary period of the experiment in order that it might become accustomed to its use before the beginning of the digestion trial.

The digestion experiments with meat were carried out after the completion of the grain experiments and it was soon recognized that a modification of the collection apparatus would be necessary. The excrement from exclusive meat feeding contains a large amount of water in contrast with that from grain food. The watery portion filled up the small spaces between the overlapping edges of the aluminum pan, depositing quite large amounts of urate which could not be quantitatively removed from these places. It did not seem feasible to swab out the apparatus with dilute sodium hydroxide, as considerable ammonia might be lost. The advisability of employing rubber-covered cloth bags was considered and they were found to fulfill the purpose quite satisfactorily. Draw-string bags were made provided with small loops about the margin, to which cloth tape was tied in strips. The strings were passed over, at the sides, and under the body, meeting in front of the wings. A decided advantage of this arrangement was the freedom of the animals from irritation. The material proved to be impervious to water, held its position well when carefully applied, and allowed of easy transfer of the excrement.

METHOD OF PRESERVATION OF THE EXCREMENT.

In the first five experiments the collection pan was removed once daily, in the remaining tests it was detached both morning and afternoon. The removal in the morning was carried out at the same time each day in order that the exact weight of the excrement for the twenty-four hours might be ascertained. This double removal of the excrement during the day was carried out to prevent, as far as possible, fermentation, with a loss of ammonia. Repeated tests always indicated that traces of free ammonia could be detected in the freshly excreted material. To arrest this fermentative process and consequent loss of ammonia, the excrement was transferred as quickly as possible from the collection pan to a casserole and stirred under 95 per cent alcohol. The excrement was dried by evaporation of the alcohol on the steam bath, the alcohol being renewed if required. Poda⁶⁰ reports excellent results from the application of this method to human feces. In order to prevent the volatilization of any free ammonia which might be

present, it was necessary to acidify slightly the alcohol. Hydrochloric acid was found unsatisfactory, owing to its charring action, but acetic acid fulfilled the requirement perfectly. The excess was readily driven off with the boiling alcohol, care having been taken at the beginning to add a minimal quantity of the acid. The samples were readily dried in this manner in one to two hours. Vigorous and persistent scraping was required to effect a satisfactory transfer from the collection pan, and while a slight amount of aluminum was undoubtedly also removed, it is of no significance, as the digestion coefficient for inorganic matter can not be estimated in the present experiments (see p. 8.)

At the close of the experimental period proper, after thorough scraping, the aluminum pans were washed quantitatively with a 1 per cent solution of sodium hydroxide in order to remove any slight traces of uric acid adhering thereto. A slight loss of ammonia ensued, but in all probability is within the limits of error. The amount of uric acid thus obtained was quantitatively determined and the result added to that observed for the excrement for the total period. After the completion of the drying process, the daily sample of excrement was transferred from the casserole to a weighed glass-stoppered bottle, a few drops of chloroform being added as a precaution against the formation of molds.

THE METHODS OF ANALYSIS ADOPTED.

The methods of analysis followed in this investigation may be considered under the following heads: (1) Preparation and sampling of the food and excrement; (2) Organic matter; (3) Crude proteid; (4) Metabolic nitrogen; (5) Uric acid; (6) Ether extract; (7) Ammonia; (8) Crude fiber; (9) Pentosans; (10) Nitrogen-free extract; (11) Soluble ash and silica.

PREPARATION AND SAMPLING OF THE FOOD AND EXCREMENT.

The grain designed for feeding—oats, corn, or wheat—after being thoroughly cleaned as described on page 26, was widely spread out in a thin layer from which various portions were selected. This process was repeated with the grain so selected until a sample of about 400 grams was obtained. This material was ground to a fine powder and a representative sample of about 50 grams was selected for analysis.

The handling of meat in metabolism experiments, is much more difficult than is the case with grain. W. J. Gies⁶¹ has proposed an improved method for preparing and preserving meat for such experiments, and the writer has followed the procedure with very satisfactory results. A quantity of beef sufficing for the digestion experiments planned was washed with cold water and freed as far as possible from all extraneous fat and connective tissue. Especial care was exercised

to prevent contamination with any foreign material. The beef was then passed twice through a sausage machine and was afterwards chopped as finely as possible. It was then rolled up into balls of convenient size, inclosed in cheese cloth, and subjected to gradually increasing pressure in a large meat press. After three to four hours the meat seemed to be exhausted of liquid as far as practicable; it was then thoroughly kneaded and spread out in a thin layer. As quickly as possible three samples were taken for the determination of moisture. These samples were made up of small portions selected from various parts of the material and placed in tightly stoppered, weighed glass bottles. Portions for analysis were similarly taken and placed under alcohol. The remaining meat was rapidly rolled up into balls, weighing 25 grams each, incased in waxed paper, and placed in a large glass jar. This was surrounded by a freezing mixture in the refrigerator, and the meat was thus kept frozen and perfectly fresh throughout the period of the experiment. On removing the meat from the jar and wrapper no evidence of separated fluid was seen in any case.

The meat sample selected for analysis was thoroughly ground under alcohol in a mortar. It was subsequently transferred to a convenient receptacle and heated over the steam bath to expel the alcohol, which was once renewed to insure the greatest possible drying of the meat. The material was then ground in a mill and readily reduced to a powder which furnished a very satisfactory sample for analysis.

Extraordinary care was required in preparing the excrement samples, from both the grain and meat, owing to the heterogeneous character of the material. The large proportions of silica and crude fiber present in the grain excrement rendered the selection of representative samples particularly difficult. The uric acid, as indicated by little white areas, is ordinarily scattered very irregularly throughout the feces. The air-dried samples were repeatedly ground until they were as finely divided as possible. Extreme precautions were taken against loss of material in this process. Much time and labor were required in the case of the samples of oats excrement, owing to the very large amount of fiber present. The whole of the excrement procured from one experimental period was ground and sampled for analysis. The samples in the case of both the food and excrement were preserved in well-stoppered, weighed glass bottles, and the moisture content determined at frequent intervals when analytical operations were in progress. In the selection of portions for analysis, care was observed to shake the main sample thoroughly and to select small quantities from different parts of the material. As the sand and fiber tend to settle toward the bottom, it was thought that in this way a sample as representative as possible would be obtained. In the analysis of the grain excrement samples weighing from 2 to 3 grams were employed, for it seemed unwise to use smaller quantities in view of the hetero-

geneous character of the excrement. In the case of meat excrement smaller samples could be employed, owing to the smaller ash and higher uric acid content.

Moisture was determined in all samples by drying in a Carr's⁶² vacuum oven at 60° C. with a vacuum of 22 to 27 inches. It was noted that the excrement tended to hold the last traces of moisture very tenaciously and readily took up water again, thus necessitating rapid weighing.

ORGANIC MATTER.

For reasons which have been previously presented, the digestion coefficient for inorganic matter in poultry can not be estimated without a previous operative procedure to separate the outlet of urine and feces. As a result of this fact the percentage of assimilated dry matter fails of estimation. The digestion coefficient for organic matter, however, is capable of indirect determination. Obviously, the excrement comprises more than the metabolic and the undigested organic matter of the food; it also includes the urinary organic matter. Hence the latter quantity must be deducted if the amount of organic matter in the feces is to be ascertained. The organic matter of the excrement corresponds to the total solids minus the sum of the water, inorganic matter, and ammonia. The great bulk of the organic matter of the urine is represented by uric acid, and the deduction of the quantity of this body from the organic matter of the excrement yields the approximate amount of organic matter in the feces.

It is recognized that there are two slight sources of error involved in this calculation: First, the fecal material contains metabolic organic substances in the form of bile acids and pigments traceable to the bile, mucous, and epithelial debris from the walls of the gastrointestinal tract, traces of the gastric, pancreatic, and intestinal juices, indol and skatol from intestinal putrefaction, etc.; second, the urinary fraction of the excremental organic matter contains, besides uric acid, traces of organic substances, as urea, purin bases, etc. The error involved in these two connections is probably very slight and of little or no practical significance. The actual digestion coefficients, however, are somewhat higher than represented in the tables of these experiments.

CRUDE PROTEID.

The various methods for the estimation of proteid matter in food-stuffs were considered, but serious difficulties were encountered in the application of any of them to the excrement. The methods of direct determination presuppose either that the proteid of the material in question is soluble in water or that treatment with hot water under certain conditions of precipitation will remove the nonproteid nitrogenous matter. Little or no information, however, is at hand with

reference to the chemistry of the proteids of the excrement following the feeding of corn, oats, wheat, or beef, and we possess no definite information as to the details of the changes undergone by these proteids in their passage through the gastro-intestinal tract of the fowl.

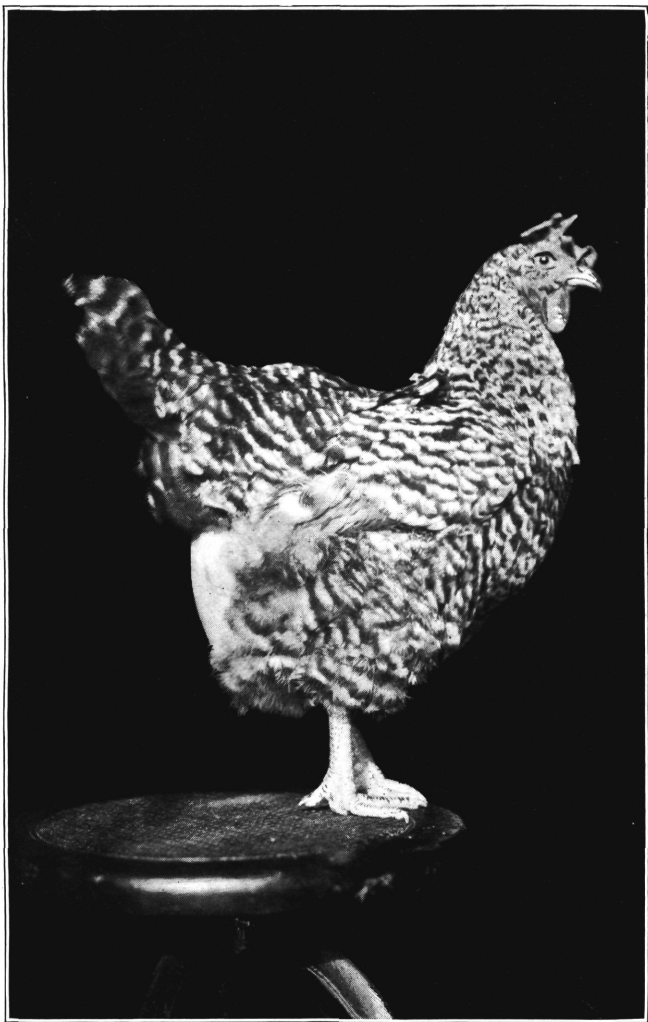
It should be kept in mind that a certain fraction of the excrement proteid may be in the form of zein, and hence insoluble in both cold and warm water. Furthermore, any water-soluble proteid may have been rendered insoluble by coagulation in the drying process over the steam bath. Again, a considerable fraction of the nonproteid excrement nitrogen may be dissolved in the form of uric acid on extraction with hot or cold water and, although dilute alkalis will completely remove uric acid from the excrement, proteid matter is liable to be also involved in the solution. The method of Stutzer⁶³ directs that the material to be analyzed be extracted with hot water to bring all soluble proteid matter into solution. It will be remembered that this proteid so dissolved is precipitated by copper sulphate; the original residue together with the precipitate is thoroughly washed with hot water to remove amid bodies. In Mallet's⁶⁴ method the proteid is assumed to be wholly dissolved by warm water.

Several investigators have estimated the crude proteid of the feces of farm animals by digestion with pepsin and 0.2 per cent HCl. The nitrogen rendered soluble by such treatment has been assumed to represent the crude proteid. In applying this digestion method to the excrement the writer has observed that not only does a fraction of the uric acid enter solution, but the total ammonia is necessarily dissolved by the hydrochloric acid. Hence control determinations would be required on the amount of solution of these substances. The control tests must be performed with 0.2 per cent HCl alone, and we have no certainty that this reagent may not have a solvent action on the crude proteid of the excrement. Furthermore, the estimation of uric acid in the 0.2 per cent HCl extract of the excrement is not practicable owing to the large admixture of pigment. As will be pointed out later, absolute alcohol has proved a fairly satisfactory solvent for the removal of the coloring matter of the excrement. However, Chittenden and Osborn⁶⁵ have shown that certain grain proteids—namely, the zeins—are soluble in dilute alcohol, and we have observed that absolute alcohol removes a proteid-reacting substance or substances from the corn and the oat grain. Hence removal of coloring matter from the excrement by absolute alcohol may involve a loss of proteid matter as well.

The application of the digestion method to the excrement of poultry does not seem feasible unless a separation of the urine and feces has been effected. Paraschtschuk⁶⁴ has studied the matter under these circumstances and his results will receive detailed consideration later



THE COLLECTION PAN, ATTACHED.



THE COLLECTION PAN, ATTACHED—SIDE VIEW.



THE COLLECTION PAN, WITH FASTENINGS.



THE COLLECTION PAN, WITH FASTENINGS—SIDE VIEW.

on in this paper (see pp. 59, 60). It was decided in view of the above considerations to determine proteid matter indirectly.

The nitrogen compounds of the excrement may be classified in four groups: (1) Ammonia, (2) uric acid, (3) crude proteid, and (4) metabolic substances of the feces and bodies in the urine exclusive of ammonia and uric acid.

In the present experiments the data for the nitrogen of the total excrement on the one hand, and uric acid and ammonia on the other, have formed the basis for the calculation of the nitrogen of the crude proteid. Total nitrogen was determined by the Gunning modification of the Kjeldahl method. The methods for the estimation of uric acid and ammonia will be described later. The sum of the uric acid and ammonia nitrogen was deducted from the total nitrogen and the result multiplied by the usual factor for crude proteid—6.25. It is fully recognized that the use of this factor is not wholly satisfactory. Distinctive factors have been recommended for different grains, based on the chemical composition of the proteids in these materials. However, the question of the factor employed would not affect the accuracy of the digestion coefficient, provided the proteid of the feces has the same percentage of nitrogen as the digested proteid matter. On this point we have at present no positive data. The different individual proteids of the same grain may show a varying digestibility, and thus the same factor may not apply to both food and feces.

The crude proteid of the grain was calculated in the customary manner by estimation of the total nitrogen and multiplying this result by the same factor as employed for the excrement. It has been pointed out by several workers that all of the nitrogen of corn, oats, or wheat is not present in the form of proteid matter. Thus a fraction of the nitrogen in some grains may appear as amido acid or amines; Richardson and Crampton,⁶⁶ in 1885, isolated allantoin from wheat germs; Frankfurt⁶⁷ also was able to demonstrate the presence of asparagin in the same material; Frankfurt and Schulze⁶⁸ observed that wheat germs and sprouting barley contained betain and cholin—bodies belonging to the class of amines. It is clear that the presence of such substances must involve an error in the analysis for crude proteid; on the other hand, such an error tends to counterbalance that incurred by the presence of metabolic nitrogen in the feces.

METABOLIC AND "RESIDUAL" NITROGEN.

In the calculation of crude proteid in the excrement we have left out of consideration that fraction of the excrement nitrogen included above under (4) in the grouping of the nitrogen compounds. The correction for metabolic nitrogen in ruminants, horses, and hogs may make the digestion coefficient considerably higher. Thus Bartlett and Merrill,⁶⁹ and Jordan and Merrill⁷⁰ determined the digestion coefficients

for crude proteid of 15 food materials in sheep. On applying the correction for metabolic nitrogen, the average increase in the value of the digestion coefficients was 10 to 11 per cent. Bartlett⁷¹ fed timothy hay, corn, and skim milk to sheep, and by the application of certain solvents he claimed that 30 to 45.5 per cent of the total nitrogen was extracted in a presumably nonproteid form. Patterson⁷² estimated the digestion coefficient for crude proteid in steers using rations of corn stover, silage, and grain. When the metabolic nitrogen was taken into account the percentage of assimilation was raised 9 per cent.

Obviously it is thus highly desirable that the metabolic nitrogen of poultry excrement be determined from the point of analogy with ruminants, horses, and hogs. The admixture of the urine with the feces, as previously pointed out, greatly complicates the matter and involves more serious difficulties than are met with in the other classes of farm animals.

Attention must also be paid to the urinary nitrogen in forms other than uric acid and ammonia. This is present as urea, purin bases, and probably other unknown bodies. It is apparent that the solution of this question would be greatly simplified if the urine and feces were separated by means of an artificial anus.

The accuracy of many of the methods designed for the quantitative analysis of metabolic nitrogen in the feces is not yet demonstrated. Ether, hot alcohol, hot water, and cold limewater have been employed as solvents. As we have already pointed out, the hot alcohol may extract proteid matter of the class of zeins. The use of limewater is open to some criticism, as this reagent dissolves mucin—a gluco-proteid. The procedure of subjecting the feces to digestion with 0.2 per cent HCl and pepsin has been utilized, the undissolved nitrogen being regarded as that fraction of the fecal nitrogen in the metabolic form. This method has been used by both German and American investigators and in many cases has yielded results comparing favorably with those secured by successive extractions with the several solvents referred to above. A criticism of this plan lies in the possibility of the solution of nitrogen material other than proteid.

The use of hot water and limewater is precluded in the case of poultry excrement, owing to the presence of uric acid, and for the same reason the pepsin-digestion method does not appear applicable. In several samples we have estimated the nitrogen dissolved, respectively, by ether, 95 per cent alcohol, absolute alcohol, and acetic ether. These data are presented in Table VIII and are discussed on pages 57 and 58.

URIC ACID.

It may be appropriate to consider briefly some of the more important properties of uric acid before considering the analytical methods for the determination of the same in poultry excrement. Uric acid is

a member of the class of bodies known as the diureides, in which the residues of two urea molecules are united to a carbon-containing nucleus. Thus uric acid was synthetically prepared by Horbaczewski on heating urea with trichlorolactamid, and it is of interest in this connection that Minkowski⁹ found that the uric acid in the urine of the goose deprived of the circulation through the liver could be largely replaced by ammonium lactate. (See p. 12.)

Pure uric acid forms a white powder and presents crystals of small rhombic form of more or less prismatic or tabular type. It is very difficultly soluble in cold water—1 part to 15,000; it is less insoluble in boiling water—that is, 1 part in 2,000. Pure uric acid is not dissolved by ether or alcohol. It was formerly regarded as being rather less insoluble in dilute mineral acids than in water, but more recent investigations⁷³ throw some doubt on the matter. Concentrated sulphuric acid dissolves uric acid without decomposition and on freezing the solution a crystalline sulphate separates out. It is readily dissolved by the hydroxides and carbonates of the alkali metals and by the organic basic bodies, piperidine and piperizine.

Uric acid has many of the properties of a dibasic acid. It forms three classes of salts. If uric acid be dissolved in a solution of sodium carbonate an acid urate is obtained, which compound is soluble with difficulty in water. On dissolving in sodium hydroxide a second hydrogen atom is replaced and the neutral urate ($C_5H_2Na_2N_4O_3$) results, which is readily soluble in water. The uric acid salts of the heavy metals are practically insoluble. The third order of salts—the quadriurates—are of special physiological interest. They may be prepared by boiling uric acid with dilute solutions of acetate of potassium, and from such a solution the quadriurate separates either in an amorphous or crystalline condition. As the quadriurates are so readily broken up into acid urates and uric acid on treatment with water, their solubility in this menstruum has not been determined. The evidence indicates, however, that they are even less soluble than the acid urates. Sir William Roberts⁶ has elaborately investigated this type of urate and considers that the uric acid salt of the blood and urine is present in the form of the quadriurate. He has shown that in all probability uric acid exists in the urine of the bird as ammonium quadriurate, $C_5H_4N_4O_3 \cdot C_5H_3(NH_4)N_4O_3$.

In the few digestion experiments which have been carried out with poultry the method of von Knieriem⁷⁴ has been employed for the estimation of uric acid. A few slight modifications have been suggested, but it is performed essentially as follows: The weighed quantity of excrement is extracted with a boiling dilute solution of sodium or potassium hydroxide. The alkaline extract is filtered, the residue thoroughly washed with distilled water, and the filtrate, plus the washings, acidified and evaporated to small volume. The concentrated solu-

tion is allowed to stand in the cold to insure as complete a separation of uric acid as possible. The crystals of uric acid may then be determined gravimetrically, or total nitrogen may be estimated and a calculation made therefrom.

Much improvement over this method is demanded if reliable data are to be obtained. The uric acid is precipitated from the alkaline solution deeply pigmented and admixed with more or less extraneous organic material which presumably interferes seriously with the accuracy of either a gravimetric or nitrogen determination. Dr. Thomas Clarke, working in this laboratory, substituted a 5 per cent solution of borax as the solvent in place of sodium hydroxide. The filtration of the extract consumed less time with this modification, but much foreign matter still separated with the uric acid on acidification. The borax extract combined with the washings (together making 200 to 250 c. c. in volume) was set aside for the separation of uric acid. In check experiments we have demonstrated that a considerable proportion of the uric acid fails to precipitate from such a large volume of fluid, and unless concentration to a low volume is carried out the results obtained are misleading.

Another modification of this method has been employed by Grost.⁵¹ It is a reasonable assumption that at least a portion of the extraneous matter thrown down from these alkaline extracts by acid is in the form of proteid matter. This investigator attempted to remove this material from the extract before the separation of uric acid. The filtered sodium hydroxide extract of the excrement was diluted to a very large volume and slightly acidified, when filtration was immediately carried out. Grost states that the precipitate readily separated in flocculent masses and that filtration was performed before uric acid had apparently deposited. The filtrate was concentrated to a small volume, and, after standing, the uric acid was filtered off and weighed. This modification appears to us to be open to some criticism. No control tests on its accuracy are reported, and small quantities of uric acid separated during the process of filtration may have been overlooked.

The writer has considered the feasibility of the reliable methods employed in the estimation of uric acid in human urine. It may be said at the outset that in all of these methods it is necessary, as a preliminary step, to effect its solution. The alkali employed to this end is very likely to also remove proteid matter. Hence it is desirable to utilize a method in which the proteid and uric acid may be separated from each other or in which the presence of proteid material will not act as an interfering factor.

With the use of the Ludwig-Salkowski⁷⁵ method it seems probable that the proteid would be precipitated by the ammoniacal silver solution and redissolved on the decomposition with hydrogen sulphide. The applicability of the method of Hopkins⁷⁶ was also tested. A very

dilute borax extract of a weighed amount of excrement was saturated with ammonium chloride, when the material separated in flocculent masses. After standing several hours the material was collected on a small filter and thoroughly washed with a saturated ammonium chloride solution. The precipitate was then transferred to a small beaker with hot water, acidified, and evaporated to a volume of about 25 c. c. The precipitated crystals appeared mixed with other organic matter, which, although present in small amount, precluded either weighing or accurate titration of the uric acid with potassium permanganate.

Jolles^{77, 78} has reported a method which rests on the assumption that uric acid under certain appropriate conditions will yield all of its nitrogen in the gaseous state when decomposed by sodium hypobromite. This method did not appear sufficiently established to justify its trial in these experiments.

It has long been known that piperidine is a ready solvent for uric acid, the easily soluble salt, piperidine urate, being formed in the reaction. Tunncliffe and Rosenheim⁷⁹ by utilizing this fact have devised a volumetric process for the determination of uric acid in human urine. They first showed that pure uric acid could be quantitatively titrated against a N/20 solution of piperidine, phenolphthalein being used as the indicator. The operation, as applied to the uric acid of the urine, was carried out in the following manner: The uric acid from 100 c. c. of urine was separated according to the directions of Ludwig-Salkowski, collected on a filter, and washed acid free. It was then transferred to a small dish with about 25 c. c. of water and titrated at boiling temperature against a N/20 solution of piperidine. Check determinations performed with the Ludwig-Salkowski method, in which the uric acid was weighed, demonstrated a very satisfactory agreement. The obvious advantage of this method as applied to poultry excrement is that the presence of proteid material does not necessarily interfere with the titration.

Kionka,⁸⁰ in a paper published in 1899, tested the adaptability of this method to the excrement of hens, and reported satisfactory results. Very small samples of meat excrement—0.2 to 0.3 grams—were selected and extracted with repeated portions of a mixture of equal parts of alcohol and ether to remove coloring matter. It is apparent that if the excrement were now titrated with a solution of piperidine that ammonia would be generated and interfere with the reaction. Kionka removed the ammonia quantitatively in the following way: The sample was treated with a little dilute hydrochloric acid to liberate uric acid from any of its salts; the mixture was left standing for several hours to allow for the separation of any uric acid which might have entered solution. Filtration was then carried out and the residue washed to free from hydrochloric acid. The excrement was now transferred by

means of 25 c. c. of water to a small beaker and directly titrated as prescribed by Tunnicliffe and Rosenheim, against a standard solution of piperidine.

Kionka employed a N/5 solution of piperidine in place of the N/20 solution used by these authors. Some criticism with reference to this method occurred to the writer. It will be noted that the samples selected for analysis were of very small quantity, and it seems questionable whether or not they would be sufficiently representative of the material analyzed. In digestion tests with grain at least the large amounts of sand and fiber present would necessitate the use of far larger samples if concordant and accurate results are to be obtained. The error of using small samples would be correspondingly greater than in the analysis of the excrement from meat feeding, and particularly in view of the fact that the uric acid content is strikingly greater in the latter material. It also appeared that the use of a N/5 solution of piperidine involved a much greater liability to error than the employment of a N/20 or N/10 solution. Thus in Kionka's analyses 0.1 c. c. of the piperidine solution was equivalent to 3.36 mg. of uric acid. Thus in view of the small amounts of excrement employed and the high percentage of uric acid a slight error would be tremendously multiplied.

A further criticism has reference to the possibility that the excrement may contain material which, in addition to uric acid, reacts with piperidine. Kionka makes no mention of any experiments designed to test this possibility. The writer's experiments in this connection with grain excrement will be presently considered. The method was first submitted to the test of repetition, samples of grain excrement of 2 grams weight being employed and a piperidine solution of N/10 strength. Great care was used to obtain uric acid of absolute purity for the standardization of the piperidine solution used in all of the analyses. A specimen of uric acid prepared by Kahlbaum was three times recrystallized from solution in dilute sodium hydroxide by precipitation with hydrochloric acid. The crystals were washed with distilled water until no further trace of chlorine could be detected in the wash water. They were then treated successively with absolute alcohol and ether, and finally dried to a constant weight at 105° C. The nitrogen content was determined in duplicate, with the result that the criterion percentage of purity was obtained. From 0.1 to 0.2 gram of the crystals was taken and titrated against an approximately N/10 solution of piperidine at a temperature slightly below boiling, phenolphthalein being added. The crystals readily dissolved and the end point was reached in two to three minutes. The titre of the solution was redetermined weekly, but was found to show no appreciable change in intervals less than one month.

Considerable difficulty was confronted in the exact determination of

the end point of the reaction, which was obscured to a certain extent by both the quantity of the suspended excrement to be handled and the pigment in the solution. A more effective method of judging the end point was performed as follows: A perforated platinum disk was sealed in the end of a long glass tube and covered with a thin layer of asbestos. A portion of the fluid was drawn through this into the tube, and solid particles being excluded, the tint of the solution could more readily be seen. The duplicate data yielded by this method were not wholly satisfactory, and it was felt that some improvement must be instituted before the results could be accepted with confidence.

The mixture of equal parts of alcohol and ether recommended by Kionka proved ineffectual in removing sufficient coloring matter from the excrement. The action of a number of solvents on 2-gram samples was tried in this respect and care was taken to ascertain whether any extraction of uric acid had been effected. Ether, benzol, amylalcohol, and acetic ether gave unsatisfactory results. Uric acid could not be detected in these extracts, but in each case the residue yielded further pigment on extraction with 95 per cent alcohol. This latter reagent, however, removed a trace of uric acid from the excrement. Absolute alcohol afforded the most satisfactory results in this connection and exerted no solvent action on the uric acid of the excrement in the grain experiments. A trace was removed, however, from the meat excrement, but it was too minute to be determined. Samples weighing 2 or 3 grams were extracted with successive portions of boiling absolute alcohol of 25 c. c. each. The residue from the first two extractions yielded a faint Scherer's test, but the additional extractive fluids resulted negatively. The number of extractions required to exhaust the excrement was dependent on the nature of the grain that was fed. Four successive treatments with 50 c. c. of boiling absolute alcohol usually sufficed for the excrement from oats feeding, but in the case of the corn samples two or three additional extractions were necessary. Four extractions removed the bulk of the pigment, but the seventh filtrate from the meat excrement still showed a faint color.

The method, in the form which we finally adopted it, was applied as follows: The material to be analyzed was thoroughly shaken and a sample, weighing from 2 to 3 grams in the case of the grain and $\frac{1}{2}$ to 1 gram in the case of meat excrement, was selected by taking small portions from various parts of the mass. The grain samples were extracted with successive 50 c. c. portions of absolute alcohol and the meat samples with 25 c. c. portions, until all soluble coloring matter had been removed. It was then allowed to dry, after which it was treated with 25 c. c. of 0.5 per cent HCl, stirred, and left in the refrigerator overnight. The material was filtered off the following morning and washed twice with water to remove the bulk of the adhering hydrochloric acid. Extraction was now carried out with an excess of boiling

N/10 piperidine solution, two to three drops of phenolphthalein being added as the indicator. The solution was filtered and the residues were washed with hot piperidine solution. The filtrate and washings were combined, the solution was acidified with hydrochloric acid, evaporated over the steam bath to a volume of about 25 c. c., and placed in the ice box. After the lapse of two or three days the separated uric acid was collected on a small filter, washed with just sufficient water to remove all traces of hydrochloric acid, and transferred to a small beaker with about 25 c. c. of distilled water. A little phenolphthalein was added and the titration conducted with a N/10 piperidine solution as described above.

As a further check upon the accuracy of the method of titration with piperidine, I have added pure uric acid to samples of previously determined uric-acid content and estimated the percentage recovered. Six trials of this character were undertaken. The following data are typical of the results: 0.1074, 0.1681, and 0.1321 gram of uric acid were, respectively, added to 2-gram samples of oats, corn, and wheat excrement, and the corresponding percentages recovered by the method were 97.3, 97.5, and 98.9 per cent.

Mention should be included here of some additional observations in connection with this method. Great care was exercised to remove all traces of hydrochloric acid from the excrement. Thus it has been calculated that for every milligram of hydrochloric acid present, a plus error of 3.65 mg. of uric acid would be involved in the titration with piperidine. Hence the presence of a relatively slight amount of the mineral acid may thus introduce an appreciable error in the uric-acid determination. That the excrement itself contains acid-reacting material was shown by the acid reaction of aqueous and alcoholic extracts toward litmus and congo-red paper and by the behavior of the same toward a N/10 solution of piperidine. As has been pointed out before, the slight impurity separated with the uric acid consisted of deeply pigmented amorphous material. The uric acid itself contained but little pigment and frequently crystallized out in absolutely colorless condition. This amorphous material dissolved on adding a few drops of piperidine to the hot liquid. This fluid was transferred to another small beaker, thus leaving in the first vessel practically all of the uric acid to be determined. The transferred solution was now titrated to the end point. The uric acid remaining behind was then treated with 25 c. c. of distilled water, the indicator added, and the titration was completed. It was thus found expedient to titrate the great bulk of the uric acid in a solution practically free from coloring matter. The quantity of uric acid dissolved served as a signal to the approach of the end reaction. The latter, however, occurred slightly subsequent to the entire solution of the uric acid, due presumably to a certain solvent action of the hot water on the substance.

The writer's attention was early called to the fact that the chemically pure uric acid, as shown in the standardization of the N/10 piperidine solution, dissolved more rapidly in this reagent than the same body separated from the excrement. It was at first thought that the absence of impurities associated with the pure uric acid might account for this result. That uric acid existed in a much more finely divided condition than in the case of the other material was also recognized. Samples of uric acid from the excrement were therefore finely ground and titrated, and the difference now very largely disappeared. This modification, however, was not attempted in the quantitative operations owing to the tendency to loss of material.

A curious fact was noted with regard to the determination of the end point of the titration. When the pink color indicating the conclusion of the titration was reached and the fluid was permitted to stand until cool, the tint deepened quite markedly. On heating to the boiling point, the previous faint color was restored, but was again intensified on cooling. In the case of other samples, the titration was stopped when the amount of piperidine added fell within 0.2 to 0.3 c. c. of producing the end color. When the titration fluids had cooled, a faint pink color manifested itself. The writer is not aware that similar observations have been previously recorded. While no explanation is offered at present for these results, it is suggested that under the experimental conditions, a slight dissociation of the piperidine urate occurs at room temperature. However, this matter had no practical bearing on the accuracy of the method.

ETHER EXTRACT.

The customary method recommended by the Association of Official Agricultural Chemists⁸¹ was employed. From 2 to 3 grams of the material were dried to constant weight in vacuo at 60° C. and extracted in a Knorr's extraction apparatus for twenty-one hours. After drying and weighing the process was continued a day longer in order to insure a complete removal of the ether extract, but no additional weight was lost. The unsatisfactory nature of the present methods for fat estimation is very obvious. The ether extract in both the grain and excrement contains considerable material other than true fat represented by waxes, organic acids, pigment, etc. If such constituents passed through the digestive tract unabsorbed, the error involved would be largely counterbalanced. However, the metabolic products of the feces may comprise appreciable quantities of ether-soluble material in the form of cholesterin, organic acids, and pigments from the biliary secretion. It is thus desirable to devise methods for the determination of the nonsaponifiable material in the ether extract of both food and feces. The application of such a correction may elevate the digestion coefficient for fat to an appreciable extent.

AMMONIA.

The method of Schlossing⁸² was given consideration, but seemed to be of inconvenient length and involved the possibility of the decomposition of the proteid matter and other nitrogenous bodies by bacterial action. Distillation with very dilute sodium carbonate was undertaken, but it was found impossible at the start to carry out the distillation, owing to the extreme foaming induced by the saponification. This difficulty was obviated by utilizing the residues from the ether extract for this purpose.

It was also deemed possible that the sodium carbonate might exert some destructive action on the proteid of the excrement. Hence the method of distillation with magnesia⁸¹ was next attempted, and was found to require less time and manipulation. The results obtained were slightly lower than those yielded by the distillation with sodium carbonate, but within the limits of error. The possibility has not been overlooked that a fraction of the nitrogen of urea and possibly other extractive bodies may pass over as ammonia, but this slight error would tend to counterbalance the error committed in overlooking such substances in the crude proteid calculation.

CRUDE FIBER.

The Weende⁸¹ method was followed, although it is realized that the results obtained are not of satisfactory accuracy. Other methods have been proposed in recent years, but none as yet seem of established reliability. It has been demonstrated that the so-called crude fiber of foodstuffs is merely a mixture of true cellulose, oxycellulose, lignin, etc., the proportions of these various components differing according to the source of the material and to the time of action and strength of the solvent used.

PENTOSANS.

The directions of Tollens, as modified and adopted by the Association of Official Agricultural Chemists⁸¹ were followed. It was noted that a much longer period of drying was required for the phloroglucol precipitate than is called for in the outline of the method. Hence it was found convenient to shorten the drying process by the selection of smaller samples of the material according to a recommendation recently made by the official association.

NITROGEN-FREE EXTRACT.

This component was calculated in the excrement as follows: The sum of the percentages of the following substances was computed, namely, moisture, ash, crude proteid, ether extract, crude fiber, uric acid, and ammonia. This result was deducted from the total dry matter, the difference yielding the nitrogen-free extract.

SOLUBLE ASH AND SILICA.

Care was exercised to select particularly large samples (3 to 4 grams) for the ash determinations, owing to the high proportion of inorganic matter in the excrement. The combination was conducted in porcelain dishes in a muffle at the lowest possible red heat. Soluble ash and carbon were determined according to the official method.⁸¹ Especial care was taken to render the total silica insoluble. The ash, being treated with hydrochloric acid of specific gravity 1.115, was repeatedly evaporated to dryness over the steam bath and prolonged heating carried out between the successive evaporations.

DETAILS OF THE PRESENT EXPERIMENTS.

The preliminary period of each of the experiments consisted of five days, during which time the collection pan was employed. As previously stated the pan caused considerable irritation at first, but this soon disappeared.

In the first four experiments the chickens were daily offered slightly more grain than they consumed. The grain was fed for two weeks prior to the digestion experiment, the average daily requirement being thus ascertained. The food consumption did not show any great irregularities after three to five days. In the fifth trial the quantity fed was somewhat less than the appetite demanded, in order that an absolutely uniform daily consumption might be assured. It is recognized that this uniformity so gained may be somewhat incompatible with normal conditions if the food requirement was not fully met. It will be noted that in the case of subjects B and C marble was made available with gravel, but the respective amounts of these materials consumed were not determined. (See Table VI.) Gravel was withheld from chicken G both during the experimental period and for several weeks prior to that time. This experiment will receive special comment in connection with two trials with oats, in which the subjects were similarly deprived.

GENERAL SCHEME OF THE EXPERIMENTS.

The general scheme of the experiments is presented in Table I. The chickens are designated by letters, and when more than one test was carried out with the same chicken the order of their performance is indicated by a small number placed at the upper right of the letter. The total weight of the air-dried excrement in column 4 represents that of the material after being dried and ground for analysis. The other features of the table seem to be self-explanatory.

Table II records, for the entire series of experiments, the daily consumption of food and water, the output of excrement, and the body weight; also the date and duration of each trial. The relation of daily

weight of food and excrement calls for comment. Obviously the conditions of the experiment with chicken A are not wholly satisfactory, owing to the irregular food consumption during the first nine days. The data for the last four days, however, show but little variation. This fact, as well as the great length of the experimental period, would tend to counterbalance these fluctuations. It will be noted in the various experiments that the variations in the elimination of the excrement do not necessarily show an orderly correspondence to the fluctuation of grain ingestion. This feature of the results is even conspicuous in the experiment with chicken G, when the daily intake was practically uniform. This circumstance would seem to be accounted for by an inherent tendency of the chicken to irregularity of excretion. Such facts emphasize the need of experimental periods of sufficient length to overcome this source of error so far as possible.

COMPOSITION OF THE FOOD AND EXCREMENT.

The analytical data of the foods consumed are to be found in Table III. Sample 1 of corn formed the ration in experiments with chickens A, B, and C; sample 2 was fed to chickens D and G. Sample 1 of oats was employed in all of the experiments with this grain excepting that with chicken H, in which sample 2 was used. The wheat sample was employed with chicken A, this being the only wheat test that was satisfactorily completed. The beef sample was used for the experiments with chickens M and N.

Table IV exhibits the analytical data of the air-dried excrement. The variation of the samples in silica content is very conspicuous, ranging from 0.88 per cent in chicken N to 28.48 per cent in chicken C, and as the silica ingested is practically a neutral factor as regards absorption it was decided to render the data of the excrement samples more comparable by calculating the same on a moisture-and-silica-free basis. Accordingly, the data in Table V comprise the results of this computation.

THE CORN EXPERIMENTS.

Table VI shows the digestion coefficients and the balance of income and outgo of the nutrients in the corn experiments. One additional trial which was undertaken could not be completed owing to an attack of diarrhea on the third day. It may be here remarked that with this single exception the animals maintained a normally vigorous condition throughout the experiments. The appetite continued good and the excrement was of normal odor and consistency.

DIGESTION COEFFICIENTS.

Organic matter.—The digestion coefficient for organic matter in the corn experiments (Table VI) is seen to be relatively high and shows

but little fluctuation in the different tests. These slight discrepancies may be assigned to a variety of causes, such as idiosyncrasy of the animal, irregularity of food ingestion or excretion of feces, varying quantities of fecal metabolic products, etc. Jordan and Hall,⁸³ in discussing some data compiled with reference to this question, write:

In some instances the animal which gives the maximum coefficient with one food shows the minimum coefficient with another food. In no series of experiments with the same animals do the coefficients as a whole have a consistent relation with reference to individuality. It is evident that either the animals digested their food more efficiently at one time than at another or else there was an irregularity of excretion, or both. It seems reasonable to regard the former of these factors as the more influential, especially when the feces are collected for five to seven days.

Crude proteid.—Crude proteid is seen to possess a high availability, the average digestion coefficient falling somewhat below that for organic matter. The digestion coefficient for crude proteid presents greater variations in the different experiments than is seen in the case of organic matter. Such a result might be anticipated in view of the larger number of sources of error connected with the determination of this nutrient. Thus in the present experiments a correction for metabolic nitrogen has not been introduced, and this figure may exhibit relative variation in different experiments; the ready tendency of the fresh excrement to ferment with loss of nitrogen is another source of error. Furthermore, as crude proteid in the present experiments is estimated indirectly, there is a greater tendency to error than by a direct determination, for relatively slight errors in the estimation of uric acid and ammonia may be increased to appreciable quantities when their bearing on the calculation of crude proteid is considered.

Ether extract.—The utilization of the fat of corn presents a high value, and, with the exception of the case of chicken G, the data of the experiments are in excellent agreement. The experiment with chicken G calls for special mention, as the animal had no access to gravel. The lower proportion of the fat absorbed may be due to this fact, but, on the other hand, the assimilation of organic matter, crude proteid, and nitrogen-free extract is not significantly lowered. It will be noted that chickens F and H, as recorded in Table VII, digested the ether extract of oats only slightly less efficiently than the other subjects, although they were deprived of sand. The factor of individuality may have a bearing on the result noted in the case of chicken G.

It appears of interest in this connection to refer to a recent communication of St. Weiser and Zaitschek⁸⁴ on the composition and formation of goose fat. These observers fed very large quantities of maize and millet to geese, the average amount of corn daily ingested being 210 grams, that of millet 317 grams. They concluded that the body fat formed from these grains is of practically the same composition. The fats of maize and millet, though quite different in many

respects, are assimilated in such small quantities that they do not appreciably affect the large amount of fat formed from the carbohydrates of the grains. The digestion coefficient for the fat of maize as computed from their data is only 39.13, as contrasted with the corresponding average figure of the writer for hens (see Table VI) of 85.32. The difference may be referable to the enormous quantities of the grain fed by these investigators, for it seems probable that the geese were unable to digest such large amounts of fat as efficiently as smaller quantities. It should also be borne in mind that these differences may also be inherent in the different species of birds compared. These considerations apply as well in the case of millet. St. Weiser and Zaitschek obtained a digestion coefficient of 43.78, while Kalugin (see Table IX) on feeding moderate rations of the grain to hens reported 85.71.

Nitrogen-free extract.—The data for the digestion coefficient of nitrogen-free extract are satisfactorily concordant throughout the series, and the availability is very high, the average figure being 89.25. The most important constituents of the nitrogen-free extract from the physiological point of view are starch and pentosans, and it was proposed in the greater number of the present experiments to estimate the digestibility of these components.

The presence of soluble sugars in the excrement was first carefully looked for as follows: Samples of corn excrement of 3 grams each were extracted on a hardened filter with 150 c. c. of 10 per cent alcohol, a total quantity of 30 grams being so treated. The combined filtrates were concentrated over the steam bath to a volume of 50 c. c. and the residual fluid allowed to stand a day in the cold. Considerable material separated out that contained much uric acid or urate. This was filtered off and the filtrate treated according to the customary procedure for the phenylhydrazine test. The mixture was kept in the cold for several days and microscopically examined from time to time. No trace of osazone could be detected.

This negative result was confirmed by a test performed in a slightly different manner. It will be recalled that the excrement samples were subjected to extraction with boiling absolute alcohol as a preliminary step in the determination of uric acid. Five hundred cubic centimeters of such an extract, corresponding to 20 grams of excrement, were distilled until reduced to 75 c. c. This residual fluid was further concentrated to 50 c. c. over the steam bath and the phenylhydrazine test applied. No evidence of osazone was obtained. As a still further corroboration 50 grams of corn excrement were stirred with 500 c. c. of water for three hours and then filtered. The filtrate was permitted to evaporate to a volume of 50 c. c., and, after standing in the cold, was filtered and tested for osazone. In this case also no separation of osazone could be detected. These negative results suggestively indi-

cate that the excrement contained no free pentoses, and hence lead to the provisional conclusion that the pentoses of ingested pentosan material are not eliminated through the urine or intestine in unchanged form. As pointed out on page 49, pentose sugars have been demonstrated in the urine of certain mammals.

The absence of soluble sugars in the excrement has been reported in digestion experiments with other classes of farm animals. Thus Bartlett and Merrill⁸⁵ reported that the sucrose and reducing sugars in fodders, such as alsike clover, white clover, blue joint, etc., were completely digested. Ladd⁸⁶ found that the sucrose and glucose were entirely absorbed in alfalfa hay, wheat bran, corn meal, cottonseed meal, linseed meal, and oats. An exceptional result, however, was obtained on feeding turnips and mixed hay. Here the glucose was wholly assimilated, but the sucrose was available to the extent of but 78.7 per cent. Fraps⁸⁷ examined twenty-three samples of excrement from sheep to which crab grass, hay, peameal, corn bran, green rape, etc., had been fed. The conclusion was drawn that soluble sugars were entirely assimilated.

It was deemed advisable to examine the excrement qualitatively for starch before the application of quantitative methods. Five portions of corn excrement, weighing 3 grams each, were repeatedly extracted with absolute alcohol for the removal of pigment. Each sample was treated with hot water in the usual manner to gelatinize any starch present, and the aqueous extract was filtered off. Portions of 15 c. c. each of the filtrate were carefully tested with a freshly prepared iodine solution. After the addition of several drops of the reagent a faint pinkish color developed although somewhat obscured by the presence of pigment. This quickly disappeared on standing, and it was found necessary to apply several additional drops before the color would persist for any length of time. The aqueous extracts apparently contained material other than starch reacting with the iodine. The tint of the color reaction obtained suggested the presence of a trace of erythrodextrin, and as erythrodextrin is soluble in cold water its presence should be demonstrable in cold aqueous extracts of the excrement. No reaction, however, was obtained. The residues from the cold-water extraction were now treated with boiling water. The pigment had been largely abstracted by the cold water, and a distinct but faint blue coloration resulted. The misleading pinkish tinge was apparently due to admixture with pigment. The excrement from exclusive meat feeding was subjected to the above tests, but with no indication of a color reaction. A minute amount of grain excrement was ground with meat excrement, and the hot water extract of this material yielded a slightly blue color.

Samples from each experiment were microscopically examined for starch. In no case could a reaction be observed with certainty. The

starch content must therefore be exceedingly small. The only direct determination of the digestibility of starch in mammals which we have found on record was carried out by H. C. Sherman,⁸⁸ who found that the starch of wheat bran was entirely assimilated by a steer. Jordan states that he has regularly failed to detect starch in the excrement of cattle from which the unbroken grains had been removed. In view of the mere trace of starch-reacting material present in the excrement, the coefficient of digestibility of the starch alone must be very high—probably not far from 100 per cent.

St. Weiser and Zaitschek⁸⁹ have recently reported a study of the digestibility of the carbohydrates of corn and millet in ducks and geese. These observers claim that the mean of the reducing power of arabinose and xylose on Fehling's solution practically corresponds to that of dextrose. They therefore determine the pentose present in the excrement and obtain the datum for starch by subtracting the pentose figure from the total dextrose present in the hydrolyzed extract. Phosphotungstic acid was first used to precipitate reducing material other than sugars from such extracts. They report, however, that such precipitation was unnecessary, as without its use the same results were yielded. The method is open to a criticism, namely, that no mention is made of an examination of these extracts for uric acid or creatinin, which, if present, would reduce Fehling's solution.

The digestion coefficient for the starch of millet was found to be 65.80 for ducks and 91.80 for geese. The provisional deduction may be drawn that geese possess a greater digestive capacity for the starch of millet than ducks. Kalugine found that the total nitrogen-free extract in hens was assimilated to the extent of 98.39 per cent. (See Table IX.) St. Weiser and Zaitschek obtained a digestion coefficient of 95.02 for the starch of corn in geese, while the writer found that the total nitrogen-free extract of this grain was utilized in poultry to the extent of 89.25 per cent.

We have not as yet developed a satisfactory procedure for the determination of starch in the excrement, but plan to devote some study to the matter. In the application of the diastase method, uric acid and possibly other substances are brought into solution which actively reduce Fehling's solution.

Pentosans.—Considerable variation in the different experiments is manifest in the digestion coefficient for this nutrient. Such a tendency is not surprising in view of the close association of a part of the pentosan with the crude fiber and the varying values of the digestion coefficients for the latter nutrient. In two of the three experiments recorded in Table VI with regard to this matter, the pentosan material is seen to possess considerable digestibility, but the availability is very appreciably less than has been claimed for other classes of farm animals. It is possible that in fowls the ingestion of pentose sugars may

lead to the excretion of the same through the kidneys in unaltered form. Ebstein³ observed that when xylose was fed to rabbits it appeared in unchanged form in the urine. Salkowski¹ and Cremer² found that when arabinose and xylose were fed to rabbits or men, about one-fifth appeared in the urine in the same form as ingested. The muscles contained arabinose, and glycogen formation was promoted in the liver. Salkowski reported that the administration of arabinose to fowls notably increased the hepatic glycogen content and a portion of the pentose sugar was found in the excrement. How far this quantity represented material absorbed and eliminated by the kidneys could only be determined under conditions of a separation of the excretory channels of urine and feces.

St. Weiser and Zaitschek⁸⁴ studied the availability of the pentosans of millet in ducks and geese, and of maize in geese. The average digestion coefficient for millet was 21.70 for the duck and 24.10 for the goose. The assimilation of starch, on the other hand, was over 25 per cent greater in the case of the goose. The pentosan of corn was utilized to the extent of 24.20 per cent by the goose.

As indicated on page 47, the pentosans of the grain fed in the present experiments apparently did not give rise to the excretion of free pentoses. An experiment of interest in this connection was performed by Cross, Bevan, and Remington.⁹⁰ The pentosans of a weighed quantity of brewers' grains were subjected to hydrolysis with a dilute mineral acid. The acid fluid containing the free pentoses was neutralized, evaporated to small volume, and administered to a rabbit in conjunction with carrots, gelatin, etc. The animals utilized from 94.5 per cent to 98.4 per cent of the material, and no pentose or other furfural-yielding products were detected in the urine.

Crude fiber.—The digestion coefficients for crude fiber show considerable variation, which may be explicable on several grounds. The work of certain observers has shown that the crude-fiber residue will yield an appreciable quantity of pentosans when subjected to the operation for pentosan determination, and this fact alone demonstrates a lack of accuracy in the method. Furthermore, it should be emphasized that little or nothing is definitely known regarding the chemical changes undergone by cellulose in the alimentary canal. It is not known with certainty whether the data yielded by analytical methods actually represent the total quantity of unabsorbed fiber, for a fraction of the cellulose may be transformed into soluble products which, passing unabsorbed into the feces, would involve a plus error in the quantity of the nitrogen-free extract.

In addition to the deficiency of analytical method, idiosyncrasy may have a bearing on the variations of the present experiments. Fluctuations in the quantity of grinding material of the crop might be sup-

posed to exert an influence in this connection, but the data of Table VI do not bring out any orderly variations in this respect. Chicken G, however, assimilated but a minimal amount when entirely deprived of sand. An examination of Wolff's⁹¹ compilation of digestion coefficients shows that other classes of animals show wide fluctuations in the digestion coefficients for crude fiber, and in the majority of cases these variations are much greater than are observed in the data for the other nutrients.

It is of interest to note that St. Weiser and Zaitschek⁸⁴ find that the crude fiber of millet is unassimilated by ducks and geese, and the same result was yielded in the case of geese with corn.

THE OATS EXPERIMENTS.

The data obtained from these experiments are shown in Table VII. It will be noted from the general outline of these tests comprised in Table I that two digestion trials, with oats, were made with chickens A and C. The tests with oats presented somewhat more difficulty in the matter of obtaining satisfactory experimental conditions than the corn experiments. Two additional experiments were gotten under way with other animals than those designated, but owing to the production of a mild diarrhea they were discarded.

The daily statistics of food consumption, weight of excrement, water intake, and body weight are recorded in Table II. The daily ingestion of oats is considerably less than that of corn, and the monotony of the single diet is more distasteful to the fowls in the case of the former grain. The daily grain consumption does not present any striking variation with the single exception of chicken A². The oats were given *ad libitum*, except in the case of chickens B² and E, when the amount was limited to what the animals would in all probability have eaten entire. While the daily excrement does not present a constant correspondence to the weight of the daily food, the trend of variation of the former tends to follow that of the latter.

Owing to the higher percentage of crude fiber in oats this diet calls for a greater consumption of sand than is demanded during corn feeding; hence the excrement contains a far greater percentage of ash and fiber as compared with that from corn. A representative sampling for analysis was rendered more difficult than was experienced with the excrement from corn feeding. Great labor was necessitated in grinding the samples to the requisite degree of subdivision, and the necessary precautions were observed against loss of material during this process. In six of the eight experiments gravel was offered *ad libitum*. Chickens F and H were deprived of this material for several weeks prior to and during the digestion period. In the test with chicken C² marble was mixed with the gravel.

DIGESTION COEFFICIENTS.

Organic matter.—The degree of agreement of the digestion coefficients for this nutrient in the different experiments appears good in view of the possible unavoidable sources of error noted under the discussion of the corn trials. The minima and maxima, respectively, are seen to be 60.28 and 67.60 per cent. The assimilation is conspicuously lower than is shown by the corresponding figures of the corn experiments, the average difference being 21.87 per cent in favor of the corn. This matter is brought out more sharply on the graphic chart at the end of this bulletin.

Crude proteid.—As was noted under the corn experiments, the range of variation for the digestion coefficient of this nutrient is greater than is observed in the case of organic matter. The range of variability extends from 70.80 to 80.53 per cent in the experiments with the subjects which received gravel. The digestion coefficient in the case of chicken F, which had no access to sand, is quite a little lower. On the other hand, the datum for chicken H is but slightly less than the average of the subjects receiving grinding material. The mean value of all the digestion coefficients is about 10 per cent less than that of corn, a difference of considerable economic significance, which will be referred to in another section of this paper.

It may be mentioned at this point that the error incurred in overlooking the metabolic nitrogen is relatively less than in the corn experiments, as obviously follows from the fact of the greater relative percentage of crude proteid in oats. We are also aware that the character and amount of the metabolic nitrogen may vary with the various grains fed, and closely associated with this matter is the question of the quantity and nature of the nonproteid nitrogen of the food.

To what causes may the lower availability of the crude proteid of the oats be assigned? The proportionately greater quantity of crude fiber present, as compared with corn, may exert a protective influence on the crude proteid, thus tending to shield a portion from the full action of the gastric and pancreatic enzymes. The inferior palatability of the oats and the smaller consumption, as compared with corn, are also possible factors. On the other hand, the crude proteid of oats may possess an inherently lower digestibility, aside from other influences. This possibility gains additional weight in view of the observation that the individual grains of oats regularly appear in the excrement thoroughly disintegrated. The excrement of chickens F and H, which received no sand, did not apparently differ in appearance in this respect from that of the other subjects which had received a full quota with the food.

Ether extract.—The series of digestion coefficients for this constituent exhibit a little greater variation than was observed in the corn experiments; the highest and lowest values being, respectively, 85.44

and 77.19 per cent. The mean availability is slightly less—about 3 per cent—than the average for corn, but the difference is hardly of sufficient size to carry economic weight. It is important, however, to consider that despite this slight discrepancy, the oats grain contains an appreciably smaller content of ether extract as compared with corn. With regard to the crude proteid, however, the reverse relation holds true; while the percentage of crude proteid is greater in oats, there is a pronounced difference in favor of the availability of this ingredient in corn.

The residues from the ether extracts of the excrement from both corn and oats were examined for the presence of cholesterin-like material by a method described on page 86. Crystalline material was obtained readily responding to the Salkowski reaction with sulphuric acid and chloroform. The writer is not aware that either the excrement or the bile of birds has ever been examined for the presence of cholesterin. As both corn and oats contain phytosterin, it seems probable that the material here isolated may partly owe its origin to the cholesterin-reacting substance of the food as well as of the bile. Regarding the exact form of the cholesterin of the excrement, nothing can be said here, as the reduction processes of the intestine vary in different animals both as to character and extent. Thus the horse excretes a modification of cholesterin known as hippokoprosterin;⁹² in the feces of the dog it is eliminated unchanged; while in the intestine of man koprosterin is the distinctive term for the altered cholesterin found. Thus it appears plausible that the bird may excrete a peculiar modification of this body. In view of the relative shortness of the intestine and the rapid digestion in birds, it seems likely that less bacterial action would come into play and hence less modification of cholesterin material in the alimentary canal as compared with the animals above referred to.

Nitrogen-free extract.—The digestion coefficients for this constituent are much inferior in value to those of corn, as would be inferred from a comparison of the data for organic matter. The limits of variation for all the experiments with oats are 65.19 and 74.99 per cent. The mean value for the digestion coefficient of corn is 18.48 per cent higher than the corresponding figure for oats. The larger percentage of crude fiber in the oats may be in part responsible for this difference. If this is the case the crude fiber would appear to depress the availability of the nonstarch components of the nitrogen-free extract as the assimilation of starch seems to be nearly complete. Repeated qualitative tests were applied to all the samples of excrement as described under analogous experiments with corn, and a slight positive reaction could be demonstrated, except in case of chicken H. There seemed to be mere traces present in accordance with the results of the corn experiments. The absence of soluble sugars in the corn excrement was also found to hold true for the samples from the oats experiments.

Pentosans.—There is a lack of uniformity in the digestion coefficients for this nutrient throughout the series. This finding is not surprising when the wide variations in crude fiber assimilation are given due regard. As is indicated on page 48, a tendency to a correspondence between the digestion coefficients of these nutrients would not seem inconsistent. Aside from the second experiment with chicken A, the general trend of the data point in this direction. The availability of the pentosans of oats in poultry, on the basis of our experiments, appears to be much lower than has been observed by Fraps⁸⁷ in digestion trials with sheep on this grain.

Crude fiber.—The proportion of crude fiber utilized is seen to show considerable fluctuation, varying in the experiments where the subjects were given access to sand from 4.25 to 10.64 per cent. The general tenor of the data indicates a lower absorption than that noted in the tests with corn, but owing to the greater quantity of the constituent consumed in oats, the absolute amount assimilated exceeds that of corn. Broadly speaking, the crude fiber of oats seems to be of insignificant food value and more particularly when considered in connection with the digestion coefficient of this nutrient in other classes of animals.

Having already briefly considered some of the possible causes to which discrepancies in the different experiments relative to crude-fiber absorption could be attributed, the writer would add here the suggestion that variations in the retention of fibrous material in the alimentary canal may be a factor in this connection. At any rate it seems plausible to suppose that the physical nature of such material would render it more liable to irregularity of excretion than in the case of the other nutrients.

As observed in the corn series, the consumption of sand and assimilation of crude fiber seem to show no orderly variations. Chickens F and H apparently utilized crude fiber as efficiently as the other animals, despite the fact that they had not consumed sand for three weeks. Such observations tend to support the contention that fluctuations in the value of the digestion coefficients are not, essentially at least, associated with variations in the sand ingestion.

THE WHEAT EXPERIMENTS.

Although six digestion experiments were undertaken with wheat but one of the series was completed. This difficulty was due to the digestive disturbances engendered by the exclusive use of this grain. After varying periods of a few days, the animals exhibited a marked loss of appetite, with general symptoms of bodily depression, and the feces emitted a markedly abnormal odor. Diarrhea was early manifested. On changing the diet to corn or oats the appetite was rapidly regained, and general normal conditions were soon restored. The following is descriptive of a typical experiment: An active, vigorous

hen was fed 50 grams of corn daily for a period of two weeks, the appetite remaining keen during this time and the daily consumption uniform. The daily ration was now changed to the same quantity of wheat. The note-book record shows that the consumption for the first day was 40 grams, that of the second 35, of the third 29, and of the fourth 22, on which date the feces appeared of abnormally soft consistency and a marked putrefactive odor was manifest. On reverting to the corn ration these unfavorable symptoms disappeared within forty-eight hours.

Our experience has been paralleled by Dr. Thomas Clarke, who carried out five wheat-feeding tests with fowls, only one of which was completed under normal conditions.

In Table II are included the daily statistical data of the single experiment which was completed with chicken A. The suggestion may be offered that this animal may have resisted the untoward effects of the diet by virtue of idiosyncrasy. The writer would also emphasize the point that he fully realizes the limited value of results based on but one digestion test, and therefore offers the data with a greater reserve than in the other experiments.

DIGESTION COEFFICIENTS.

The daily consumption of food in this experiment was maintained at practically a uniform level, and there is a rough correspondence between the slight irregularities of food ingestion and the output of excrement. The assimilation of organic matter is but slightly less than the utilization of this nutrient in corn. The digestion coefficient of crude proteid is intermediate in value between that of corn and oats, but is nearer the latter.

The most conspicuous feature of these results is the low digestion coefficient for the ether extract. This observation is doubly significant when associated with the inferior proportion of ether extract in wheat. If further experiments confirm this indication, the result will assume a most important bearing on the use of this grain in poultry dietaries. The injury to the fowl following the exclusive use of wheat may be due to the poorness of the grain in fat and the low availability of this nutrient. It may be of interest to mention that Grost observed in hens a very low assimilation of the ether extract of rye, a grain which somewhat resembles wheat in its low percentage of ether extract. No reference, however, is made to any interference with the digestive processes. Pflüger²³, has published an observation which should be mentioned in this connection. He found that the exclusive feeding of horse meat led to a marked diarrhea in dogs, and suggests that this result may be partly assignable to the deficiency of the tissue in fat.

The nitrogen-free extract of wheat in this experiment is digested in a proportion only slightly less than that determined for corn. Quali-

tative tests, carefully repeated, failed to demonstrate the presence of soluble sugars in the excrement of this animal; starch was not searched for.

The data for crude fiber are not recorded in the table owing to the fact that the content of this substance in the excrement slightly exceeded that of the food. The first estimation of crude fiber was made in duplicate in both the food and the feces. The results so obtained were confirmed by a further duplicate determination. Irregularity in excretion may be concerned with this discrepancy, and it is possible that crude fiber retained from the preliminary period is eliminated with that fraction belonging to the wheat of the collection period. While the time of the present experiment would seem to be sufficient to acquire definite data on the point just referred to, it is necessary to considerably prolong the period to place the matter beyond doubt.

THE MEAT EXPERIMENTS.

The data on the composition of the meat employed in the two experiments with this diet are presented in Table III. Tables IV and V exhibit the composition of the excrement. Each experiment was preceded by a preliminary period of five days, during which time the same daily quantity of meat was given as in the digestion period. The chickens had received a sole meat diet since the date of purchase, three weeks prior to the beginning of the preliminary period. During the entire time no digestive derangement resulted, nor were any of the symptoms present described by Kionka (see p. 23) as ensuing from excessive meat feeding. The daily ration was immediately and readily consumed throughout the preliminary and digestion periods. The monotony of the diet did not markedly interfere with the palatability, as was seen in the grain tests, but the small quantity of material offered may be concerned with this difference. Although the subjects suffered a very gradual but progressive loss of weight, greater bodily activity and vigor was maintained than in the digestion experiments with the grains.

DIGESTION COEFFICIENTS.

In view of the fact that only two meat experiments were performed, it is realized that even greater reserve should be exercised in a consideration of results than in the grain experiments. The balance of income and outgo with the digestion coefficients is presented in Table VII. The agreement between the two experiments is seen to be quite satisfactory in the case of all three nutrients considered—that is, organic matter, crude proteid, and ether extract. Nitrogen-free extract is disregarded, owing to the minimal quantity of carbohydrate material in meat. A closer agreement between the digestive coefficients for the nutrients of meat would be looked for than in the

of grain in view of certain analytical considerations. The estimation of the crude proteid of meat yields more accurate data than is the case with corn or oats. This follows from the high content of proteid matter in the dry meat and the corrections introduced for peptone, albumose, and meat-base nitrogen. The meat excrement possesses a higher content of crude proteid than the material from grain feeding, and this difference renders the error of indirect determination of this constituent proportionately less. The strikingly high quantity of uric acid in the meat excrement would a priori insure a smaller error of analysis, and this same consideration applies to the ammonia.

A cursory glance at the comparative analytical data on the composition of both the food and resulting excrement brings out sharply the more heterogeneous character in the case of the grains. The absence of carbohydrate and crude fiber, at least in appreciable quantities, from meat indicates that sampling for analysis would be the more satisfactory with the food and excrement in the meat experiments. This would also incline us to the view that the digestion coefficients for organic matter in different experiments would result in closer agreement. It should also be borne in mind that a correction for "residual nonproteid nitrogen" was taken account of in calculating the percentage of the meat excrement proteid. This nitrogen represents at least a part of that not in the form of crude proteid, uric acid, or ammonia. It was estimated as follows: Three grams of excrement were weighed out and heated with 300 c. c. of water over the steam bath for thirty minutes, the loss by evaporation being replaced from time to time. The water was now allowed to boil for a few minutes, when filtration was carried out. The filtrate was made up to 500 c. c. in a properly graduated flask. Total nitrogen, ammonia, and uric acid were estimated in aliquot portions. A large number of tests demonstrated that no proteid matter was removed by these hot-water extracts. The nitrogen, exclusive of uric acid and ammonia, was calculated from the data obtained, and the correction applied in the calculation of crude proteid. The writer has not overlooked the consideration that there may be "residual nonproteid nitrogen" in the excrement undissolved by hot water.

COMPARISON WITH GRAIN COEFFICIENTS.

It may be of value to contrast the average digestion coefficients of the meat nutrients with the corresponding figures obtained in the grain tests. The assimilation of organic matter and ether extract does not depart noticeably from the values obtained for corn. Crude proteid is utilized to a greater extent than was found in the case of corn. This high value for crude proteid is particularly significant as associated with the strikingly high proportion of proteid material in meat. It would be of interest to determine the coefficient for crude proteid

after the ingestion of larger quantities of this article of diet. It appears not improbable that with extremely large quantities the coefficient would be lowered, especially if the amount consumed overtaxed the digestive capacity of the animal.

The proportionate quantity of ether extract in the meat consumed is less than that included in the grains fed. The value of the digestion coefficient, however, does not indicate any essential difference in the digestive capacity of the chicken for animal and vegetable fat. It is planned at a future date to undertake digestion studies with beef when the material is consumed with a balanced diet of a predetermined digestibility. In this way it may be determined whether the digestion coefficients of the meat fed as a sole diet differ from those when it is combined with other food materials.

In the above considerations of the digestion coefficients of the writer's experiments, it should be borne in mind that the digestibility of the nutrients may show some variation under conditions differing from those here imposed. Thus unrestrained exercise in the open air would tend to raise the general body metabolism, and hence increase the digestion coefficients over the value secured under conditions of experimental confinement. The possibility must also be considered that the availability of the grains may undergo some modification when fed as part of a mixed ration rather than when consumed as a sole article of diet. The proportion of fibrous material in the ration must be considered. The relative palatability may also show some change when the grain in question is offered as a component of a mixed ration. Thus the proportionate consumption of oats to corn may increase when the two grains are fed together. In the open air and with access to a wide range, the appetite of the animals, even for the single grains, would tend to increase, and the augmented consumption would in all probability lead to increased weight as compared with the same under experimental conditions such as those described in the present paper.

THE METABOLIC NITROGEN OF THE EXCREMENT.

In Table VIII the few data obtained for nonprotein nitrogen of the excrement removed with various solvents are tabulated. The determinations obtained with the extracts of 95 per cent alcohol were found to be misleading, as slight traces of uric acid were demonstrated in the residues from such extracts. These extracts also contained an organic amorphous nitrogenous substance which is further described on page 87, and may consist of alcohol-soluble protein. It can not be said at present whether this is a metabolic product or derived from the grain. The term "fecal nitrogen" as employed in the table includes not only the nitrogen of the feces, but additionally the urinary nitrogen, exclusive of uric acid and ammonia. Table VIII shows that the "fecal nitrogen" of the excrement samples from chickens B and

C in the corn experiments contained 70.33 per cent and 59.88 per cent, respectively, of nitrogen abstracted by 95 per cent alcohol. The sample from the second oats experiment with chicken A comprised 46.36 per cent metabolic nitrogen.

The importance of apparently insignificant amounts of metabolic nitrogen should be fully recognized in experiments with poultry, in which animals the absolute quantity of nitrogen daily excreted is so small. Thus the excrement of the corn experiments with chicken B yielded only 0.12 per cent of ether-soluble nitrogen, but a correction for the same raises the digestion coefficient for crude proteid from 86.63 per cent to 87.98 per cent. In the oats experiment with chicken B the ether-soluble metabolic nitrogen was 0.12 per cent and the corresponding correction elevates the digestion coefficient from 79.39 to 80.11 per cent. In the second oats experiment with chicken A a correction for 0.10 per cent raises the digestion coefficient 2.72 per cent. The correction for acetic-ether nitrogen in the case of the last-named experiment and of chicken B² is seen to be rather greater than in the corresponding ether extracts.

The nitrogen removed by absolute alcohol was determined in the case of two experiments. These results are of doubtful value, owing to the probable solution of the organic amorphous nitrogenous material, which may be proteid in nature, and which was noted in the residue from the 95 per cent alcoholic extracts. It appeared to be removed to a slight extent. When the crude proteid calculations for the experiments with chickens E and F were checked for this nitrogen value the percentage of absorption in the former case was altered from 72.65 to 77.17 per cent, and in the latter from 67.75 to 74.07 per cent.

As to the form or forms of the metabolic nitrogen extracted by ether or acetic ether, little may be said here. Bile pigments, lecithin, and certain decomposition products of the bile salts may be dissolved by ether. Little is known relative to the composition of bile or the modifications undergone by the constituents in the intestines of the fowl. It appears probable that absolute alcohol extracts metabolic nitrogenous material in addition to that removed by ether, despite the fact that the former reagent may dissolve a certain quantity of zein proteid. The excrement, as we have previously observed, contains considerable mucus, and this material, in addition to the nuclein of desquamated cells of the alimentary tract, may contribute much of the metabolic nitrogen. These two sources may largely account for the high percentage of metabolic nitrogen observed by Paraschtschuk⁵⁴ (see next page). The comparison of the average digestion coefficients for organic matter and ether extract indicates a satisfactory agreement between the results of the present experiments and those of Paraschtschuk, and the same statement applies to the nitrogen-free extract. Paraschtschuk makes no mention of an examination of the excrement for starch.

A COMPARISON OF THE PRESENT WITH PREVIOUS EXPERIMENTS.

The averages of the digestion coefficients of corn are presented in Table VI and those of oats in Table VII. These averages are tabulated together in Table IX, and are graphically represented in the smaller chart at the end of this bulletin. Table IX was constructed to bring out the comparison between the data of the present experiments and those published by other experimenters relative to the digestive coefficients of poultry. There have also been included average digestion coefficients established for other farm animals under conditions of diet as closely analogous as could be found.

We would call attention to the unreliability of the average coefficients of digestion for crude fiber in the corn and oats experiments. In view of the rather wide variations in results, it seemed misleading to attach any importance to such figures. References will be made to some of the sources of variation to be considered in the comparison of the digestion coefficients of the same diet presented in Table IX.

EXPERIMENTS WITH CORN.

In the second line of Table IX the average digestion coefficients for corn established by Paraschtschuk⁵⁴ are presented. Owing to the artificial anus established in the subjects of his experiments, his data are not strictly comparable with those of our digestion trials. No mention of the accessibility of gravel is made and the very small quantity excreted by the animals would indicate that none had been offered. Furthermore, this investigator claims that approximately 50 per cent of the fecal nitrogen exists in the metabolic form for which a correction is applied in the calculation of crude proteid. It is seen that our average digestion coefficient for the crude proteid of corn is nearly 9 per cent less than that observed by Paraschtschuk. Assuming for the moment that his data for the metabolic nitrogen represent accurate values and applying his average corrective figure to our digestion coefficients, the respective results, whether coincidentally or otherwise, show an excellent agreement.

It is of importance to consider the method employed by Paraschtschuk for metabolic nitrogen with reference to certain criticism. The directions of Pfeiffer⁵⁴ were followed. A weighed quantity of excrement was digested with 1 per cent (Merck) pepsin solution in 0.2 per cent HCl for twenty-four hours. The undigested material was filtered off, washed, and the nitrogen content determined. This result was assumed to represent the metabolic or nonproteid nitrogen of the feces. No mention is made relative to a check upon the activity of the pepsin solution employed, and there was apparently no attempt made to test the undigested residue for proteid matter with a view to ascertaining whether all of this ingredient had entered solution. The possibility is not referred to that a portion of the unknown

metabolic nitrogen may be dissolved by the 0.2 per cent HCl employed. As has been previously pointed out, this method, if accurate, is not applicable to excrement samples, owing to the presence of urinary constituents.

In the light of a recent paper by Szumowski⁹⁵ it seems unlikely that the proteid matter of the excrement would be completely dissolved in a period of twenty-four hours. Szumowski performed artificial digestion tests with the zein of corn and found that the substance is dissolved only very slowly in both pepsin and trypsin solutions. Portions of a pure zein preparation were placed in active peptic and tryptic solutions and at the end of several days no marked digestion had occurred. A finely divided preparation was digested for fourteen days before complete digestion. Samples of varying weight were tested with peptic and tryptic extracts, and solution of the material was never obtained in less than seven days.

Szumowski estimates that 50 per cent of the proteid of corn is present in the form of zein. This makes it appear probable that a portion of this material would appear in the excrement. He fed large quantities of corn exclusively to geese. After varying intervals the animals were killed and the various tissues extracted with 90 to 96 per cent alcohol to remove any zein which might be present. The results were negative, showing that zein is transformed to another form of proteid before it is built up into the tissues. When injected directly into the circulation of geese it exerts a marked toxic effect and accumulates in the liver.

A substance separated from the excrement by 95 per cent alcohol, which corresponds in some respects to the properties of zein proteid, is described on page 87. If unaltered zein is actually present in corn excrement, Paraschtschuk seems to have committed an error in assuming a complete solution of the excrement proteid in twenty-four hours on treatment with pepsin solution. If so, a fraction of his data for metabolic nitrogen is probably represented by undissolved zein. This criticism is, of course, applicable to all digestion experiments in which zein-containing grain has been fed, whenever the digestion method for the estimation of metabolic nitrogen has been employed.

The writer has carried out a number of digestion tests with pepsin and hydrochloric acid. A number of samples of corn and oats excrement were digested with an active Merck pepsin solution exactly under the conditions prescribed in Paraschtschuk's experiments. In all cases the washed and dried residue from the twenty-four hours' digestion gave a distinctly positive reaction for proteid matter with Millon's test. The digestion filtrates yielded a response to the biuret reaction. A control solution of the pepsin preparation responded very faintly to this test, but the greater intensity of the reaction in the former case indicated the solution of proteid material. Egg albumen was

rapidly digested to the proteose and peptone stage in the presence of the excrement, thus intimating that the latter contained no material inhibitory to the action of the enzyme. These residues were further digested for two days and the filtrates and washed residues again examined. Positive results were obtained, thus suggesting a very gradual solution of the proteid substances. After digesting these residues for a period of a week, the residues still responded to Millon's test, thus indicating the presence of indigestible proteid or certain substances belonging to the aromatic series, such as indol, skatol, etc., reacting with this reagent. The aromatic bodies named would presumably be present in too minute quantity to respond to Millon's test under these conditions.

The writer is well aware that the solution of proteid observed in the above tests does not necessarily involve digestion of the same. The following experiment was undertaken with reference to this matter. A large number of excrement samples were exhaustively extracted with hot 95 per cent alcohol to remove as much pigment as possible. In this case the zein proteid would also be largely or wholly removed. The dried materials were subjected to digestion with 0.2 per cent HCl, without pepsin. Otherwise the conditions exactly paralleled those of the experiments just described. No proteid was found to be dissolved by the acid. It thus appears probable that water-soluble proteid matter of the excrement, if present, was rendered largely insoluble by coagulation during the original drying process with alcohol.

For several reasons the average digestion coefficients reported by Fields and Ford⁵² are not comparable with our data. The excrement in the experiments of these investigators was not obtained by accumulation in a collection apparatus during the day, but was taken from the bottom of the cage pen. It is stated that the legs of the animals were washed at the beginning and end of each digestion period and the adhering dung collected. In this way a serious loss of nitrogen by fermentation of the excrement might occur. A description of the analytical methods which were employed is lacking. Analytical data are tabulated for both "protein" and "albuminoids," but no reason is assigned for such distinction of terms, and in the literature of digestion experiments it is customary to use them synonymously. The digestion coefficients for crude proteid from both the whole-corn and cornmeal experiments of Fields and Ford are seen to be far lower than the corresponding figures reported by the writer. The data for ether extract, on the other hand, are lower in the present tests. A lack of thoroughness in the extraction with ether is a plausible source of the latter discrepancy.

The above-mentioned experiments of Fields and Ford furnish some data relating to the effect of grinding on the digestibility of a grain.

In the tests with whole corn and cornmeal no influence is manifested. The results with Kafir corn were of an inconclusive character, and the digestion coefficients of whole cowpeas exhibited but slight variations from those of cowpea meal.

EXPERIMENTS WITH OATS.

The average percentage of assimilation of the nutrients in our oats tests is contrasted with the data of the single experiment performed by Grost⁵¹. Such a comparison offers the basis for suggestive rather than definite and conclusive statement, more particularly as the results of Grost rest on the slender basis of but one trial. The digestion coefficient for crude proteid is reported as about 11 per cent higher in the writer's experiments. The character of the analytical method for crude proteid employed in the respective experiments may be responsible for this difference. The corresponding results for ether extract indicate a rather satisfactory agreement, a concordance not unexpected in view of the identity of the method employed. It will be noted that Grost finds but a trace of crude fiber assimilated. That his datum for nitrogen-free extract is at a lower value than that determined by the writer would follow from the comparison of the coefficients for crude proteid brought out above.

These differences may be also partly referable to certain features in the conduct of Grost's experiments. Thus the subjects were confined in a perfectly stationary position, in order that the excrement might be quantitatively collected, and no mention is made relative to the consumption of sand. Such close confinement without bodily exercise in such active animals may considerably depress the digestion coefficients of some or all of the nutrients, by a lowering of the general body metabolism.

EXPERIMENTS WITH WHEAT.

In the comparative consideration of the wheat experiments there are several sources of variation to be borne in mind. Kalugin^{49, 50} computed the crude proteid content of the feces on the basis of the data for total uric acid and ammonia nitrogen. The ammonia was estimated by calculation only, on the assumption that this constituent was present entirely in the form of ammonium quadriurate. While Roberts⁶ has adduced much evidence in favor of the view that the uric acid is so combined, it has not been demonstrated that all of the ammonia is present exclusively in this form. Such an error would decrease the actual digestion coefficient for crude protein. Lehmann⁵³ performed his wheat experiment under the conditions of an artificial anus and reported a satisfactory condition of the animals following the operation. As we were unable to locate the reference to his original paper, no information could be gained regarding the analytical methods pursued.

The data for organic matter from the three sources are strikingly concordant. While the digestion coefficient for crude proteid is about 20 per cent higher in the writer's experiment as contrasted with that published by Kalugin, Lehmann's figure agrees with our result. The absorption of ether extract is low in all three cases, but the finding of Lehmann is much inferior to the results secured by Kalugin and the writer. The digestion coefficients for crude fiber in these experiments are utterly at variance. Possible explanations for such confusion of comparative results have been advanced at a former place.

EXPERIMENTS WITH PEAS AND BARLEY.

In the experiments of Kalugin,⁵⁰ Lehmann,⁵³ and Grost⁵¹, the data published by Kalugin and Lehmann on the digestion coefficients of peas call for some comment. With the exception of organic matter the availability of the nutrients is the higher in the case of Kalugin's experiments. The results of the digestion experiments with barley performed by Kalugin and Grost present a notable agreement, the more striking in view of the several sources of error incident to experimental work of this character. The agreement is especially pronounced in the case of ether extract and crude fiber.

THE DIGESTION COEFFICIENTS OF POULTRY AND OTHER FARM ANIMALS COMPARED.

It is of interest to contrast the data for the assimilation of the nutrients of foodstuffs in poultry with those obtained with other farm animals under conditions of diet corresponding to each other as nearly as possible. Such comparative data are presented in Table IX. It will be noted that the digestion coefficients for ruminants, horses, and hogs, with the exception of the wheat experiments, are quoted from the compilation of Wolff.⁹¹ These data seemed to afford a sounder basis of comparison than the few American experiments available, owing to the larger number from which the average figures were drawn. In some cases comparable data could not be found in the American literature. In fact, the number of experiments on record, especially with ruminants and horses, must be necessarily small, owing to the difficulty of sustaining such animals on a diet exclusively composed of grain.

Corn.—Ruminants, horses, and hogs assimilate the organic matter of corn in approximately equal proportions. The digestion coefficients for this nutrient in poultry shows but slight variation from that of these three classes of animals. Poultry and hogs exhibit approximately the same digestive capacity for the crude proteid of corn, while the digestion coefficient for ruminants and horses is markedly less. On the other hand different relations hold true for the digestibility of the ether extract. Ruminants and poultry possess approximately

equivalent digestion coefficients while horses and hogs utilize a much smaller proportion of this nutrient. The digestion coefficients for crude fiber are much higher in ruminants, horses and hogs, although the figures for the last-named class stand the least removed in value from that of poultry. The proportionate digestibility of the nitrogen-free extract in poultry is seen to be slightly less than in the other three classes of animals.

Oats.—In a careful search of the literature on the subject we have been unable to locate experiments dealing with the digestibility of oats as a sole diet in hogs. The table, therefore, only institutes comparisons between the digestion coefficients of ruminants and horses, and poultry. The organic matter of oats is utilized in a proportion somewhat less in poultry as contrasted with ruminants and horses. The digestion coefficient for crude proteid is much inferior in poultry as compared with that of horses. Ruminants, however, exhibit only a slight superiority over the assimilation observed in poultry. In regard to the ability to digest the ether extract, there is practically no difference between these two classes of animals, while the availability in horses appears to be considerably less. We have previously called attention to the fact that the data for crude fiber in the poultry experiments show generally a lower proportion of assimilation in oats than in corn. It is an interesting similarity that the same relation holds true for this constituent in the digestion tests with ruminants and horses. As might be a priori surmised, the digestion coefficient for the crude fiber of oats is far greater in ruminants and horses than in poultry. On the basis of these comparative results, the general nutritive value of whole oats for poultry appears to be less than for ruminants and horses.

Wheat.—The few figures on record in regard to wheat afford but a slender basis for comparison. A review of the literature revealed but one study⁹⁶ of the digestibility of whole wheat in hogs, and apparently no experiments have been performed with horses and ruminants, either under conditions of exclusive wheat feeding or where the grain was fed with a basal diet of known digestibility. The digestion coefficient for crude proteid is somewhat lower in pigs than in poultry, if the data of Kalugin's and the writer's experiments are taken as the basis of comparison. Ether extract is absorbed to a slightly greater extent in the pig, while the utilization of the nitrogen-free extract appears to be less. It is of interest that, corresponding to our results in the case of poultry, hogs digest the ether extract of wheat in much lower proportion than that of corn.

Peas and barley.—Attention is called to the data contrasting the digestion coefficients of peas^{50,53} in poultry and those determined for ruminants,⁹¹ horses, and hogs. The organic matter appears to be utilized to a slightly greater extent in horses than in poultry, but in

ruminants and hogs the assimilation is very much greater. Further discussion of the comparative results seems futile, owing to the wide discrepancies between the data of Kalugin and Lehmann, the only poultry tests with peas on record. The statement seems justified, however, that the availability of the crude proteid of peas is high in all of these animals. The barley^{50,51} digestion tests with poultry seem sufficiently concordant to permit of a comparison with the results of digestion experiments secured with the other classes of animals referred to. The poultry coefficients for the crude proteid of barley are not greatly removed from those of ruminants, horses, and hogs, and they correspond more closely to the two latter classes than the first named. The organic matter is utilized to a less extent in poultry than in any of the other animals with which they are contrasted. In their capacity to absorb the ether extract poultry resemble hogs. In the case of horses the ether extract coefficient was much lower; ruminants exhibited a considerably greater percentage of absorption.

GENERAL DISCUSSION OF THE DIGESTION COEFFICIENTS.

A comparison of all the poultry digestion coefficients of Table IX reveals several points of practical interest. The organic matter of corn is digested to a greater extent than was observed in any of the other foods studied. The organic matter of peas and barley is absorbed in approximately equal proportion. The digestion coefficients for crude proteid possess the highest value in the case of corn and peas. There are but slight variations in this value as regards oats, wheat, and barley. The percentage of assimilation is considerably lower in the case of buckwheat than is recorded for the three last-named grains. The digestion coefficient for ether extract is approximately of the same value for corn, oats, and peas; slightly higher for buckwheat. Allusion has been made on page 49 to the small significance which is to be attached to the data for crude fiber. The digestion coefficient for this nutrient seems to tend to be higher in corn than in any of the other grains. Barley yields but a trace of digested crude fiber, and the percentage of utilization is slight in oats, rye, and buckwheat.

Another point of interest brought out calls for mention, namely, the conspicuously inferior absorption of the ether extract of both rye and wheat. This is particularly significant when associated with the fact that the percentage content of fat itself is very low in these grains, more markedly so in the case of rye. This low assimilation may be attributed to both the small quantity ingested as well as to the inherently low digestibility of fat itself. The high absorption of ether extract and the low availability of crude protein in the case of buckwheat are conspicuous features of the table. These comments also apply to the data quoted with reference to millet.

The discrepancies brought out in Table IX between parallel experiments from different sources make it obvious that the average data from such figures tend to be misleading. Furthermore, the number of experiments on record with each grain is too small to attach absolute certainty to the results, even when they are in close agreement. The writer offers his own data with the utmost reserve, and realizes the need of many additional tests before absolutely definite conclusions may be advanced and the coefficients of digestion utilized in compiling perfectly reliable food standards.

SOME PRACTICAL ASPECTS OF THE RESULTS.

Some practical considerations suggested by the results of the experiments of this paper, and based on the data presented in Tables X, XI, XII, XIII, and XIV, are now given. The data for the consumption and assimilation of the nutrients of corn per 100 pounds live weight refer to the tests with chickens A, B, C, and D, and in the case of oats to subjects A², B², C², A³, C³, and E. The figures here given are to be regarded as merely provisional. The data are based on experiments where the body weight of the animals did not show a marked divergence from the limits of 3 and 4 pounds. Little value, however, can be attached to the data from the single wheat experiment until confirmatory trials have been made.

It will be seen that a feeding standard for maintenance rations, compiled by Wheeler,⁹⁷ is included in Table X. These figures are not wholly comparable with our data, as they do not rest on digestion experiments with poultry, but are based on the data of a wide variety of dietary experiments, made at the New York (Geneva) Experiment Station. However, it was thought that the comparison of the respective data might not be without interest. The calorimetric calculations in Parts I and II, of Table X, were based on the factors in common use, that is, proteid 4,500, fat 9,000, and carbohydrate 4,000 calories.

FEEDING STANDARDS BASED ON THE DIGESTION COEFFICIENTS.

The comparison of consumption and assimilation per 100 pounds body weight (Table X, Parts I and II) clearly indicates the wide difference between nutritive value as based on chemical composition and that founded on actual digestibility. This is more conspicuous in the case of oats than in the other two grains. The nutritive ratio also shows considerable change. In the case of corn it is lower when computed from consumed nutrients than from assimilated nutrients. This relation is reversed in the data from the oats experiments. The assimilated nutrients of wheat, however, possess a nutritive ratio strikingly higher than in the case of the consumed constituents.

It is clear that the data of Wheeler's standard for maintenance rations, which concern hens of 3 to 5 pounds in weight, are the most compar-

able to our results. In regard to the nutritive ratio^a the finding of our single wheat experiment corresponds most closely with that of Wheeler. The nutritive ratio of the consumed and assimilated corn is much higher, while that of oats is much inferior. When the consumption and assimilation of nutrients per unit pound of body weight are considered we find that the corn standard as computed by us shows the least variation from that published by Wheeler. The main difference is in the much greater quantity of assimilated carbohydrate in our experiments. The consumption in the case of the oats experiments is obviously far below the maintenance standard, a matter which is also emphasized in the data for body weight shown in Table XII. The assimilation in the wheat experiment is also insufficient and the fat utilization particularly so, despite the fact that the nutritive ratio does not depart noticeably from that established by Wheeler.

It seems of interest to contrast the nutritive ratios in Table X with those determined for animals of other classes. The figures quoted here are taken from Mentzel and Lengerke's *Landw. Kalender* for 1899. As the rations fed in the experiments recorded by us in this paper may be regarded as practically utilized for maintenance purposes, we have endeavored to select data from experiments with other animals under as like circumstances as possible. Mention should be made at the outset, however, that on a priori considerations and under parallel conditions poultry would require food of a wider nutritive ratio than the larger farm animals. The pronounced vitality, the very rapid respiration, and the high body temperature of poultry are characteristics demanding a relatively high consumption of carbohydrate. Associated with these characteristics is the well-known law that the smaller the animal the greater is the surface area relative to bulk and the greater the relative heat production.

The comparison of Parts I and II with Part III of the table demonstrates that the assimilation per unit weight is very much greater in poultry than in the large farm animals. The relative difference is most striking in the case of the ether extract as compared with the crude proteid and nitrogen-free extract. The data in Part II indicate that the animals under severe work show a greater relative increase in the assimilation of crude proteid and ether extract than is seen in the case of the nitrogen-free extract. These comparative figures point to the probability that poultry assimilate more crude proteid and fat relative to the nitrogen-free extract than mammals. The fact that the former class of animals requires such a high proportion of the nutrients per unit body weight presupposes their adaptability to concentrated food-stuffs like the grains.

^aThe nutritive ratio represents the ratio of digestible protein to the digestible nonnitrogenous nutrients. The fat is reduced to its starch equivalent by multiplication with the customary figure, 2 $\frac{1}{2}$.

In view of the above considerations, the fuel value of the assimilated food per 100 pounds body weight is greater in poultry than in the larger farm animals compared above. It would be very desirable to directly estimate the fuel value of the assimilated food under various conditions with the bomb calorimeter. Such a study is not possible under conditions of a common pathway for the excretion of urine and feces, and it is evident that the establishment of an artificial anus would be necessary. The data for fuel value here presented are regarded as but approximations.

The comparative data representing the actual assimilation of nutrients per 100 pounds of the grain fed present several features of interest. (See Part IV of Table X.) If an equal consumption of the organic matter of corn, oats, and wheat could be effected, the wheat would presumably yield a slightly greater quantity of crude proteid than the oats. Corn, on the other hand, would yield a much smaller quantity than oats. When the ether extract is considered, these relations are quite reversed, corn yielding the greatest amount, while wheat is conspicuously deficient. With regard to the nitrogen-free extract, there is but a slight difference between corn and wheat, while the assimilation of this nutrient in the case of oats is strikingly inferior. The preceding statements are based on the assumption that the digestion coefficients would not fluctuate with varying amounts of food ingested. The latter possibility, however, must be borne in mind, and investigation in this connection is called for.

The question of palatability is of importance in connection with the value of the digestion coefficients. Thus not only is the consumption of oats much inferior to that of corn, but the actual percentage of assimilation of the proteid of oats is much less than that of corn. The proportion of ether extract in whole oats is inferior to the latter grain, and the availability of this nutrient is hence correspondingly less in oats. The inferior availability of the nitrogen-free extract of oats as compared with that of corn depends both on the lesser consumption and lower digestibility. The matter should be emphasized that in incorporating grains into poultry rations the relative palatability should be correlated with the digestion coefficients.

THE COST OF THE PRINCIPAL NUTRIENTS.

The great value of information regarding the actual cost of assimilated nutrients in the various poultry foods, such as the grains; the milling by-products, as bran, middlings, etc.; cut bone, the hays, grasses, etc., is obvious. The poultryman himself, would be competent to calculate these data, provided the digestion coefficients of the various feeding stuffs were available. When such coefficients have been established, he will be enabled to select the nutrients of the dietary from those foods which in his locality combine the highest digestibility with the cheapest cost.

In Part V of Table X we have recorded the cost of each constituent per pound of dry weight as calculated when the actual digestibility is taken into consideration. The following prices per bushel were assumed for the three grains: Corn at 60, oats at 40, and wheat at 80 cents. Although market ratio shows great fluctuation, the relative prices here adopted are thought to be fairly representative. The figures obtained are of suggestive interest. The most marked feature is the cheaper cost of the three nutrients of corn as compared with both those of oats and wheat. The crude proteid of oats costs practically 50 per cent more than that of corn and the same constituent in wheat is slightly below the cost in oats. The worth of the ether extract of wheat is conspicuously high, being over 50 per cent more than this nutrient furnished by corn. The nitrogen-free extract has a purchasing price strikingly higher for oats than the other two grains. The provisional conclusions seems justified that the nutrients of corn are not only assimilated in higher proportion, but they are cheaper than in the case of the oats and wheat. With equal consumption oats will theoretically yield a greater quantity of crude proteid than corn, but from the economic standpoint it would probably in most cases be of greater advantage to feed this constituent in the latter grain. Obviously, it would be bad economy to employ wheat for the ether extract of a ration, but the crude proteid and nitrogen-free extract of this grain may often be more economically fed in mixed rations than those of oats.

Table XI presents the values of the income, outgo, and assimilated quantities of the nutrients. In reaching these calculations it has been taken for granted that, for practical purposes, the crude proteid, ether extract, and nitrogen-free extract are the only constituents of nutritive value. The cost of these ingredients per kilo weight is given herewith:

Cost per kilogram of constituents of corn, oats and wheat.

Constituent.	Corn No. 1.	Corn No. 2.	Oats No. 1.	Oats No. 2.	Wheat.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Dry matter	2.65	2.64	2.99	3.02	3.23
Organic matter	2.69	2.68	3.10	3.15	3.30
Crude proteid	2.71	2.73	3.50	3.53	3.35
Ether extract	2.75	2.71	3.52	3.43	3.31
Nitrogen-free extract	2.74	2.74	3.51	3.52	3.35

BODY WEIGHTS AND COST OF ASSIMILATED NUTRIENTS.

The data for the daily body weight of all the animals are reported in Table XII, and the observations noted by Dr. Thomas Clarke with chickens under like conditions of diet are presented for comparison. Our data and those of Doctor Clarke present the same tendency under

similar conditions of diet. The superiority of corn over oats seems to be beyond question. Szumowski⁹⁵ also found that exclusive corn feeding led to a marked increase in the body weight of fowls. Attention should be called to the fact that the corn test with chicken G and the oats trials with chickens F and H are exceptional, owing to the non-accessibility of sand to these subjects. In dietary experiments with poultry, the changes in body weight are often regarded as an index of the sufficiency of a ration, but such changes, to be of significance, must be observed in carefully checked experiments extended over a long period of time and with due regard to all possible sources of variation. Although the experimental periods of the present tests are of short duration, the uniform tendency of results, especially when correlated with the food assimilation, indicate that the differences in weight have an actual significance. With the single exception of chicken B, the same animals show a greater body weight on corn as compared with oats. Furthermore, the general tendency under the influence of the former grain is to increase in weight, while with the latter, the trend is in the opposite direction. It will be noted that the consumption of organic matter is much greater under the corn diet, not excepting the experiments with subject B. The assimilation of proteid in the last-named animal is slightly the greater in the corn trial. The marked inferiority of the wheat diet is demonstrated by the lower weight and tendency to loss as contrasted with the corn experiments on the same animals. Little may be said here as to the nature of the increase or loss of weight noted in these experiments. Under such circumstances the respiration calorimeter would be needed. In view of the fact that the animals were fully matured, growth of tissue would hardly be expected, and so the increased weight is quite likely referable to fat. Owing to the well-known fattening property of corn, considerable laying on of adipose tissue might be looked for under these conditions. On the other hand, the monotony of the single article of diet and the depressing effect of the confinement would tend to lower the ingestion of the grain and hence retard the increase in weight.

The importance of the relation of body weight to the cost of the diet is brought out in the data of Table X (Part V) and Table XI. The value of gain or loss in body weight has been assumed as equal to 1 cent per ounce. It should be pointed out that in the corn experiments the increase of body weight is slight, the grain practically furnishing a maintenance ration; for this reason it may be said to contain within itself approximately the proportions of a balanced ration. Of the corn tests, only those with chickens A and D show an actual profit, but as the tendency to increase in weight was manifest, it appears likely that the remaining animals would have yielded a profit after a longer period. The data for the oats experiments in each case evince a loss much greater than that referred to in any of the corn trials. In

the case of chicken B, the loss is much less on the corn diet, although a slight gain in body weight was observed in the oats test. The single wheat experiment is carried out at a marked loss.

THE USE OF THE GRAINS IN COMBINATION.

With reference to the use of the three grains in combined diet, the following suggestions appear warranted. Corn may be used to contribute a large proportion of any of the three nutrients, but more particularly of ether extract and nitrogen-free extract. The impression prevails among many poultrymen that the excessive or liberal feeding of corn is too fattening unless the animal is being specifically fed for that purpose. It is further thought that injurious effects are more especially apt to follow when the chicken is denied free ranging. Our observations do not corroborate this opinion, as no untoward results followed the exclusive use of corn. However, the nutritive ratio may be too wide, when egg production is the object in view.

Oats may be utilized for the crude proteid and fat, and probably will prove of most value when incorporated as a component of a narrow ration. This grain has been regarded by many feeders as being of special value for egg production owing to its high content of proteid. The digestibility of ground or hulled oats may be greater than that of the whole grain. The writer hopes to investigate this matter in the near future.

The lack of palatability of wheat would probably be greatly reduced or might be overcome in properly combined rations. Wheat may be introduced into the dietary for the crude proteid and nitrogen-free extract. The deficiency of fat in the wheat may be supplied by that of corn, and under the latter condition it is possible that the untoward effects of the ingestion of liberal quantities of wheat would be avoided.

The results here recorded may offer at least a partial explanation of apparent confusion of results in dietary experiments with certain so-called wide and narrow rations. Thus a diet of wide nutritive ratio may serve the purpose of a ration of narrow ratio with more satisfactory results than the latter itself. This apparently contradictory outcome indicates the fallacy of basing the digestibility on chemical composition. Thus the food containing the smaller quantity of proteid or fat has yielded larger quantities of the nutrients, owing to higher digestibility or palatability or both.

THE UTILIZATION OF SAND BY POULTRY.

Tables XIII and XIV present some notes on the consumption, retention, and excretion of sand by poultry. The consumption of sand, as we might, *a priori*, anticipate, is much greater on an oats than a corn diet. This is no doubt occasioned by the greater proportion of

fiber in oats. Tables VI and VII present the ratio of sand to the dry matter of the food given, and it will be seen that the data exhibit considerable fluctuation in the different experiments.

We have already referred to the digestion experiments with chickens F, G, and H under the condition of absence of sand from the diet. Chicken F was purchased February 26, and received no sand from that time to the day of the autopsy (March 13). The daily elimination of total SiO_2 was determined from time to time and showed a gradual decrease. Thus on March 2 the excretion of sand amounted to 0.7172 gram, while on March 3 and 12 the elimination was 0.6454 and 0.3300 gram, respectively. On March 13 the animal was killed and an autopsy performed. The viscera appeared perfectly normal. The gizzard and intestines were carefully opened and 2.84 grams of gravel removed. This was finely ground and the quantity soluble in dilute hydrochloric acid was found to be 4.97 per cent. Another animal from the same farm and used as a check on chicken F contained 3 grams of gravel in the crop, of which 3.1 per cent proved soluble in dilute hydrochloric acid.

Chickens G and H, purchased May 23, had no access to gravel throughout the period subsequently observed. On June 1 chicken G eliminated 0.1868 gram and chicken H 0.9633 gram of total SiO_2 . On June 21 the quantities excreted were 0.6462 and 0.4760 gram, respectively; on July 17 the daily excretion was reduced to 0.1064 gram and 0.1211 gram. Both of these animals at the end of the digestion experiments appeared in normal vigor and tone. Chicken G weighed 2 pounds $12\frac{1}{2}$ ounces and chicken H 2 pounds $11\frac{1}{2}$ ounces. The chickens were now fed oats exclusively, but ad libitum, and were deprived of sand from that date (July 23) to October 4, when they were again weighed. The weight was now 3 pounds 3 ounces and 3 pounds 1 ounce, respectively—a slight increase. The animals were a trifle less active than in July, but otherwise appeared normal. Apparently the lack of gravel had not led to any serious impairment of digestion. But after this the animals appeared gradually to become debilitated. On December 2 an attempt was made to photograph them with the collection pan attached, but they appeared unable to satisfactorily support the apparatus. The diet was now changed from oats to corn, and some improvement ensued in the general condition of the animals, which was more marked in the case of chicken G.

Subject H suddenly died on January 5. The autopsy revealed a serous-like exudate in and surrounding the crop, but the alimentary canal appeared otherwise normal. The macroscopic appearance of the other organs appeared normal. Considerable grain was noted in the crop and gizzard. The gizzard contained ten particles of gravel of varying size, the total weighing 0.767 gram. It is a remarkable fact that the chicken should have retained this material after a lapse exceed-

ing seven months. This observation is the more striking when correlated with the fact, noted by the writer, that the chickens may excrete as much as 6 grams daily under conditions of free access to gravel. Apparently there is a provision of nature whereby the chicken may to some extent retain the grinding material in the alimentary tract when it is not further available.

Chicken I was also placed under observation on May 23. This subject received no gravel and was fed on corn throughout the experiments. The absence of sand did not appear to occasion any decrease in the customary activity of the chicken. The figures in Table XIV show a considerable fall in the daily output between June 1 and 6. Following the latter date the daily output at the intervals adopted shows no striking variations, but excretion is maintained. It would seem, hypothetically, that after a sufficiently long period the silica of the gizzard would be completely eliminated.

We have already called attention to the impossibility of a determination of the proportion of assimilation of inorganic matter without the use of some artificial method for the separation of the outlet of urine and feces. There is a possible source of error which must not be lost sight of in such determinations, and that is in the possible content of the gravel of the gizzard in soluble inorganic matter. We have noted small fractions of such materials in our examinations. The subjects employed for digestion experiments may have consumed certain amounts of lime or iron salts in connection with the grit obtained about the farm, which will interfere with the accurate estimation of pure ash in the excrement. To avoid such confusion it seems desirable to keep the animals under observation for some time prior to the digestion experiment and with an abundance of sand at their disposal. In this way the gravel previously consumed may be largely or wholly gotten rid of.

A prominent feature of the data expressed in Table XIII is the lack of proportion between the ingestion and excretion of sand. Thus chicken A² consumed 31.92 grams of sand and chicken A³ 52.1 grams, but the difference in excretion between these two tests is slightly less than 3 grams. The consumption for chickens A³ and A⁴ is practically identical, but the output of SiO₂ is nearly 40 grams higher in experiment A³. In the cases of chickens C³ and B² the consumption for C³ is over twice that for B², while the excretion for B² is only one gram greater than that for C³. In the corn test with subject D the consumption of gravel is slightly greater than in the oats experiment with chicken E, but the excretion is far greater in the oats experiment. Differences were also noticed in experiments when sand was withheld from the fowls. Thus chickens F and H present a much higher output of sand than subject G.

BODY ANALYSES OF POULTRY AND OTHER ANIMALS.

It appears of interest to contrast the composition of the bodies of mammals with data obtained in the analyses of the bodies of poultry. Jordan⁹⁸ has reported a number of results obtained by Jenter with reference to the latter subject. Thus the mean data for the composition of Leghorn hens were: Water, 55.8 per cent; protein, 21.6 per cent; ash, 3.8 per cent; fat, 17 per cent. The dry matter of the eggs, exclusive of the shell, exhibited a close correspondence in composition to that of the body of the hen. A comparison with the figures for the analysis of a calf's body, made by Lawes and Gilbert,⁹⁹ shows that the proportionate crude proteid content is rather less than in poultry, while the fat content is slightly greater. As compared with a Berkshire pig,¹⁰⁰ the fowl contains a much lower percentage of fat and a larger proteid content. Data are available, published by Lawes and Gilbert,¹⁰¹ on the composition of increase when steers are fattening. While these data are not strictly comparable with those from poultry, they are of interest in showing a far greater content of fat and a much lower percentage of proteid than in the latter animals. The point seems to be suggested that the poultry tissues contain a relatively high proportion of proteid, while the fat content is rather lower than in some of the other farm animals. We have pointed out above that the fat utilization per unit body weight relative to the proteid and nitrogen-free extract is higher in poultry than in oxen, sheep, horses, cows, and hogs. It seems probable that in birds a proportionately greater quantity of the fat and carbohydrate is utilized for the maintenance of heat and energy than in the case of the other animals named.

BEARING OF PRESENT EXPERIMENTS ON CERTAIN DIETARY STUDIES.

It would be a matter of much interest to contrast the findings of the digestion trials of this paper with those of dietary experiments with poultry performed under similar conditions of feeding in the open air with abundant opportunity for exercise. In a review of the literature only one¹⁰² such experiment has been found in which a single grain was exclusively feed. The nearest approach to the comparison desired is to select those dietary experiments in which corn, oats, or wheat formed the major component of the diet and when the value of the grain in question for egg production or increase of weight was considered. It may be said at the outset that it seems highly desirable to investigate the digestibility of a large number of dietaries which have been used for various purposes in poultry feeding. In this way much confusion with regard to the results of such dietary experiments may be cleared up and the more exact rationale of the value of such diets be determined. Information of this character will prove of worth in the correction of existing dietaries and the formation of untried food combinations for special purposes.

There are a few observations on record which have to do with the comparative nutritive values of whole wheat and cracked corn. We have been unable, however, to locate experiments in which the end sought was a comparison of either of these two grains with oats. Smith and Brooks,¹⁰³ at the Michigan State Experiment Station, carried out comparative feeding trials with whole wheat and cracked corn. Each pen of chickens received lettuce, cabbage, rhubarb, oyster shell, and green bone in addition. One pen consumed 145.25 pounds of wheat and the other 159.5 pounds of cracked corn. It required 2.62 pounds of wheat as against 2.5 pounds of corn to produce 1 pound of gain in body weight; the results therefore slightly favored the corn ration. The chickens were limited in their range in order that the food consumption might be exactly known. In a later experiment Smith¹⁰⁴ noted that 2.8 pounds of wheat and 2.77 pounds of corn, respectively, were utilized to produce 1 pound gain in body weight, a result confirming the test just quoted. James Dryden,¹⁰⁵ at the Utah Station, has also studied the comparative value of rations in which corn and wheat formed the predominant constituents. The wheat seemed to yield superior results with reference to the egg production.

At the Cornell (N. Y.) State Experiment Station,¹⁰² the influence of the following rations was studied: The one designed to be of a wide nutritive ratio was composed of cracked Indian corn and Indian corn-meal dough; the one used as of narrow nutritive ratio consisted essentially of one part of a grain mixture and two parts of skimmed milk. The grain mixture was made up of equal parts of wheat bran, wheat shorts, and cotton-seed meal. The same quantity of green clover and cabbage was added to each lot. The chickens failed to develop satisfactorily with the corn diet. One prominent feature was the lack of growth of feathers. The bones of the chickens fed on the more nitrogenous ration were found to be 50 per cent stronger than those of the other lot and a larger number of eggs were yielded than on the diet of wider nutritive ratio. The eggs, however, were of poorer quality and smaller than those from the diet of wider ratio. In the present experiments with exclusive corn feeding a noticeable loss of feathers or a tendency to weakness of any of the bone structures was not observed. It might be true that under a longer period such symptoms would become manifest. It appears plausible, more especially in view of certain experiments (to be referred to later), that the deficiency of ash in the corn diet may have been concerned with the untoward results reported.

Brooks and Thomson,¹⁰⁶ of the Hatch Station of Massachusetts, have reported some interesting experiments which were planned to ascertain the effect of certain rations of narrow and wide ratio on both egg production and body weight and contrast the nutritive value of corn and wheat. In the ration of wide nutritive ratio corn figured as

the principal constituent, while wheat formed the main fraction of the more nitrogenous diet. The results demonstrated the overwhelmingly superior character of the corn ration. The components of the narrow ration were wheat, oats, millet, wheat bran, wheat middlings, gluten feed, animal meal, cut clover, rowen, and cabbage. The wide ration was compounded of whole corn, corn meal, wheat bran, animal meal, millet, rowen, and cut clover. Two breeds of fowls were employed, and the experiments were performed in both summer and winter. In both the seasons named, and with both breeds of chickens, the results were essentially the same; that is, the wide ration yielded superior results.

The production of eggs was 23 to 91 per cent higher on the corn as compared with the wheat ration. Further advantages of the ration with the wide nutritive ratio were a greater gain in weight and the earlier molting of the fowl. The cost of the food per egg was very much less than for the animals with the wheat rations, the palatability of which was much inferior to that of corn. These results seem rather opposed to the commonly accepted idea that the more nitrogenous ration is the more conducive to egg production, but this opinion is often based on the mere chemical composition of the ration without regard to the actual digestibility. Owing to the greater palatability of the corn ration, and the higher digestion coefficients as compared with oats and wheat, the actual assimilation of proteid matter was perhaps the higher in the ration of wide nutritive ratio. Hence, these results are in accord with the conclusions of the digestion experiments of the writer. The low proportion of ether extract yielded by wheat may be a factor in the inferior value of the wheat ration. In view of these considerations, the nutritive value of wheat for poultry seems to have been rather overestimated, and if this is definitely established it should prove of much economic importance.

In the experiments of Stewart and Atwood¹⁰⁷ on the influence of narrow and wide rations on egg production, the more nitrogenous ration differed from that of wide nutritive ratio in containing ground fresh meat and bone, but a smaller proportion of corn meal. The wide ration proved less efficient, while, as we have reported above, Brooks and Thomson obtained the reverse result. A plausible interpretation would be that more proteid was assimilated from the ground meat and fresh bone of the narrow ration than from the corn meal of the wide ration.

In the experiments of Wheeler¹⁰⁸ at the Geneva (N. Y.) Experiment Station with regard to the importance of sufficient quantities of inorganic matter in poultry foods, he first noted that a ration in which about two-fifths of the proteid was supplied by animal food proved much more profitable to chickens than another supplying an equal amount of proteid largely from vegetable sources, but supplemented

by skim-milk curd. When two such rations were fed to cockerels the results were decidedly favorable to the animal food, but the difference practically disappeared with the mature animals. The chief advantages of the animal ration were the more rapid growth and earlier maturity. The difference was even more pronounced with ducklings, as the growth was over three times as rapid under the diet in which one-fifth of the protein was of animal origin.

Further experiments¹⁰⁹ were conducted to ascertain the rationale of the inferiority of the ration consisting largely of vegetable food. It was suspected that the lower ash content of the vegetable diet was connected with this difference. When this deficiency was actually supplied by bone ash, the efficiency of the vegetable diet equaled or exceeded that from the animal source. Even for laying hens, the vegetable food, supplemented by bone ash, proved equally as satisfactory, at least for limited periods. Hence there appears to be no intrinsic practical difference in the digestibility of the animal and vegetable proteid matter; but the presence of the inorganic matter in proper proportion is essential in both cases. Wheeler, however, states that a diet containing a certain proportion of animal food is rather the more enduring in its effects than a ration composed of vegetable proteid alone, even when supplemented by bone ash to bring it to the highest point of efficiency.

These considerations suggest that the single grains employed in the present experiments lacked mineral matter, and that the digestibility might be heightened on repeating these tests with the addition of appropriate inorganic matter. Experiments directed to this end should prove of much practical value. Digestion tests should also be carried out between comparative rations of corresponding chemical composition, the one containing proteid largely of vegetable origin, and employing a wide variety of grains, the other comprising proteid from animal sources, as animal meal, fresh bone, etc.

SOME MISCELLANEOUS OBSERVATIONS.

THE RETENTION OF FOOD IN THE CROP.

The period of retention of grain in the crop of chickens may be expected to vary with the rate of the digestion processes as well as the amount of grain consumed. It is obviously a matter of practical importance to ascertain the degree of regularity of passage of the grain from the crop to the gizzard, and whether the rate of conveyance varies with the quantity of food ingested. It would seem plausible that the gizzard may possess a limited capacity to receive the grain within a given time. If this proves to be the case it becomes doubly essential to employ uniform amounts of daily food. In mammals, on the other hand, the food, even if consumed in irregular

daily amounts, becomes at once exposed on deglutition to the digestive juices.

Varying amounts of grain were fed to fowls with empty crops and the time occupied in the entire passage of the food to the gizzard carefully noted. The fowls, each weighing 3 pounds 5 ounces, received 30 grams of corn each at 10.45 a. m. At 9 p. m. both crops contained a few grains, but at 10.15 the organ of one fowl was empty, while that of the other still contained a few grains. At 11 p. m. the crop of the latter fowl became empty. At 8 a. m. both chickens again received 30 grams of corn each. Examination of the crop at 8 p. m. indicated that in both cases the crop contained a little material. At 9 p. m. the organ was empty in one of the chickens, and the other was found to be free from grain at 9.30. Thirty-five grams additional corn were fed at 10 p. m. and the crops became empty on the following day at 1 and 1.30 p. m., respectively. At 2 p. m. each fowl consumed 50 grams, and the time of the disappearance noted was on the following day at 2.15 and 2.25 p. m., respectively. These observations are typical of a large number made with several fowls. The period of retention of oats in the crop was also considered, with results essentially similar to those recorded above. As observed in the case of corn, a trifling variation was shown for fowls of equal weight.

In the digestion experiments with chickens G and H, the crop was examined each morning prior to feeding. As we have recorded above, the animals were fed twice daily, the afternoon meal being eaten at 4 and that of the morning at 9.30 o'clock. In chicken G, the crop was found free from corn in the morning except on two days. The crop of chicken H always contained a few grains of oats.

NOTES ON THE COMPOSITION OF THE EXCREMENT.

In the experiments about to be described it was planned to examine the excrement for certain constituents which have not as yet been reported, or whose presence needs confirmation. There is little literature bearing on the subject of the composition of avian urine, and the few observations on record are lacking in harmony. It is obvious that this matter would be greatly facilitated if the urine and feces could be obtained in a pure condition. The admixture of the two excretions must complicate the application of the various qualitative or quantitative methods adapted to mammalian urine.

While ammonium urate forms the chief component of the urine of the bird, it is not by any means the exclusive nitrogenous constituent. Reference has been made to Lang's¹¹ paper, in which he indicates that 12.50 to 18.60 per cent of the total urinary nitrogen of geese may be in the form of material exclusive of uric acid, urea, and ammonia, and quite likely represented by bodies of the amido-acid type. Due allowance must, of course, be made for the attendant abnormal experimental

conditions, as the large intestine was ligatured in order to obtain the urine in a pure condition.

The nitrogenous substances of birds' urine, aside from ammonium urate, are present in exceedingly small quantities. In fact it must be borne in mind that the creatinin, hippuric acid, purin bases, etc., are present in mammalian urine in relatively minute quantities, and this is conspicuously brought out when the amounts of such extractives are calculated per kilo body weight. Hence the urine of animals of so low a body weight as poultry would contain in all probability but minimal amounts of such extractives if present at all. In view of these considerations very large quantities of excrement would be required to demonstrate the presence of such bodies.

In 1861 Meissner⁵ devoted considerable attention to the composition of poultry urine. He examined the excrement for creatinin under conditions of both exclusive meat and grain diet. The excrement of the meat-fed hens readily yielded creatin but no creatinin. Only minute amounts were eliminated by the grain-fed animals, and in many cases its presence could not be satisfactorily demonstrated. A much smaller quantity of creatin was contained in the excrement of hens fed with liver as compared with those on the meat ration. When creatin was administered hypodermically it was practically all recovered as such in the excrement. It seems open to question whether the creatin found by Meissner did not represent transformed creatinin, as the process of manipulation may have caused the conversion of the latter into the former substance. A large part or all of the creatin may have originated directly from that present in the meat fed. It is of interest in this connection that Mallet¹¹⁰ has found that creatinin when administered to man is largely excreted unchanged, while creatin is excreted in the form of creatinin.

Meissner claimed to have identified urea in the excrement from both meat and grain feeding, the quantity as expected being much smaller on the latter diet. Minkowski¹⁰ confirmed Meissner's statement that the urine of fowls contains urea, and he estimated that from 2 to 4 per cent of the urinary nitrogen was present in this form. In Beilstein's¹¹¹ *Handbuch der Organischen Chemie* the writer found a statement that urea is absent from the excrement after a herbivorous diet. No reference is appended for this assertion and it is opposed by the results of our experiments, to be described later.

Meissner searched the excrement of the hen for hippuric acid with negative results. He then attempted to ascertain whether the ingestion of benzoyl compounds would induce the excretion of hippuric acid, as has been established for mammals. This substance was apparently not formed. There were excreted two other bodies, one containing nitrogen and the other nonnitrogenous, which are described, but their constitution was not determined.

Jaffé³² found that benzoyl compounds led to the formation of a nitrogenous body, apparently corresponding to the substance reported by Meissner. This body was designated ornithuric acid and is analogous in structure to hippuric acid, being a condensation product of benzoic acid and diamido-valerianic acid. He makes no mention as to the presence or absence of this body from the excrement of animals which had not received benzoyl compounds. The nonnitrogenous body referred to by Meissner is not mentioned in Jaffé's communication.

Bongers¹¹² also failed to detect hippuric acid in the excrement of fowls, and found that this body was excreted as such when administered per os or hypodermically. Sodium benzoate was observed to yield 60 per cent of its benzoic acid as such in the excrement, the remainder being largely transformed to ornithuric acid. Ornithuric acid could not be found in the excrement of the animals on a mixed diet which had received no benzoic acid. It is to be presumed that those foods which lead to a pronounced excretion of hippuric acid in mammals will induce the elimination of ornithuric acid in birds. Bongers claims that the feeding of gelatin plus sodium benzoate occasioned a very marked elimination of ornithuric acid, but no hippuric acid could be detected in the excrement. Apropos of the above considerations, it may be stated that a condensation product of pyromucic acid and glycocoll, analogous to hippuric acid, has also been found in the urine of hens. Jaffé and Cohn¹¹³ noted that furfural was transformed to pyromucic acid in hens, as Jaffé had previously pointed out in the case of dogs and rabbits. Part of the pyromucic acid was eliminated as such and part in the condensation form mentioned above.

The urine of hens, in addition to the substances already described, may contain purin bases in very minute quantity. Milroy²⁰ has reported this result from the examination of urine obtained under conditions of an artificial anus.

The writer has searched the literature for statements relative to the elimination of ethereal sulphuric acid. As has been previously indicated, owing to the rapidity of the digestion processes in birds and the ill-defined development of a large intestine, there is probably a relatively small extent of intestinal putrefaction; hence a relatively small elimination of indol, skatol, and bodies of that type might be expected. Christiani¹¹⁴ detected ethereal sulphuric acid in hens' urine after a meat diet and found that the ingestion of indol leads to its excretion in the form of indoxylsulphuric acid. Schary¹¹⁵ asserts that the subcutaneous injection of phenol results in the elimination of this body in the form of ethereal sulphuric acid. Peurosch¹¹⁶ claims that the subcutaneous injection of phenol or ligation of the intestine does not cause the appearance of indoxylsulphuric acid in the urine. On the authority of Bongers¹¹² benzol, when administered to hens, is oxidized, as in mam-

mals, to phenol, and leaves the kidneys as ethereal sulphuric acid. The negative influence of extirpation of liver on the metabolism of sulphur has been already referred to at a former place.³³ These few observations show that much additional investigation is required in this connection.

In our examination of the excrement we have kept the following ends in view: To search for the presence of urea, creatinin, hippuric acid, ornithuric acid, allantoin, kynurenic acid, benzoic acid, and cholesterin-like material. It need hardly be mentioned that we have borne in mind the possible presence of substances not heretofore described.

Urea.—Samples weighing 25 grams of both the dried ground corn and oats excrement were selected for this test. The urea content of these samples would in all probability be lower than in the freshly passed excrement, as the temperature of drying over the steam bath would tend to cause decomposition. The samples were treated with 500 c.c. of 95 per cent alcohol each, thoroughly stirred and filtered. The filtrate was evaporated to dryness over a water bath at 50° to 60° C. and the residue taken up in 25 c.c. of water. The method of Mörner and Sjöquist¹¹⁷ was now followed. The solution was treated with an equal volume of a saturated solution of barium chloride containing 5 per cent of barium hydrate. The precipitate was filtered off and the clear filtrate evaporated to dryness between 50° and 60° C. The residue was extracted with 25 c.c. of cold absolute alcohol and the filtrate allowed to spontaneously evaporate to dryness. The residue so obtained appeared partly crystalline and partly amorphous. The crystals were made up of fine, long needles closely resembling urea, and the application of the urea nitrate test resulted positively. Although no quantitative determination was attempted, it was seen that the amount present in the weight of excrement taken must be exceedingly small.

Hippuric acid.—Attention has already been called to the fact that the acetic-ether extracts of the excrement contain a small percentage of nitrogen which might possibly be referable to hippuric acid. Twenty grams of mixed corn and oats excrement were employed in this test. This material had been used for the quantitative determinations of ether extract, and hence was entirely freed from fat. The substance was now extracted in the cold with two successive portions of 100 c. c. of acetic ether, and the combined filtrates of a deep orange color were distilled until the volume was reduced to 25 c. c. This residual fluid was allowed to gradually concentrate at room temperature in a large open dish. The slight residue appeared entirely amorphous. It was redissolved and again allowed to concentrate with similar result.

Another procedure was attempted with the use of larger quantities of excrement. Two 50-gram portions from corn, oats, and wheat feeding, respectively, were treated as follows: Extraction was first carried out with 600 c. c. of water, the material being stirred frequently for three hours. A few drops of a thymol solution were added to prevent putrefaction, and filtration was undertaken. This was twice repeated in order that a perfectly clear fluid might be obtained. The filtrates from the two samples were now combined and evaporated to a volume of about 200 c. c. The fluid was allowed to stand in the ice box several days. Considerable material separated out of solution, which was collected on a filter and washed with a little water. This material was preserved for future examination. The filtrate from the washings was evaporated to a thick sirupy consistency of blackish appearance. This residue was thoroughly extracted with ether, and finally with boiling 95 per cent alcohol. The latter extract was filtered and evaporated to a volume of 25 c. c., covered, and left to stand at room temperature. Considerable amorphous organic matter separated, but at the end of two weeks no substance of a crystalline character could be demonstrated. The fluid was permitted gradually to evaporate to dryness, and was examined from time to time. The residue was found to consist largely of inorganic matter. A few crystals were noted resembling urea, but the amount was too small to permit of identification. Hippuric acid, if present, would seem to be in inappreciable amounts. Creatinin was looked for in this residue, but no crystals conforming to the crystalline character of that body were recognized. The residue was redissolved in 25 c. c. of 95 per cent alcohol, 5 c. c. of 10 per cent ZnCl_2 solution added, and the fluid being covered was left to stand for the possible formation of creatinin ZnCl_2 crystals. After standing for a space of four weeks it was examined microscopically, but no crystals were detected.

The material which had separated from the aqueous extract was now submitted to an examination. It contained a large proportion of inorganic matter, and the organic fraction seemed to be largely composed of uric acid or urates. Extraction was performed with 100 c. c. of 95 per cent alcohol, and the filtrate having evaporated to 25 c. c. was allowed to concentrate spontaneously to dryness. The residue was found to consist mostly of inorganic matter and contained a few hexagonal crystals not of the appearance of hippuric acid. The quantity was insufficient for identification.

Another plan was executed as follows: The aqueous extract of 50 grams of excrement prepared as described above was concentrated to a volume of 200 c. c. and allowed to cool. Filtration was then conducted and the filtrate slightly acidified with sulphuric acid. This extract was repeatedly shaken with acetic ether and the combined extracts distilled to a small volume and permitted to evaporate to dry-

ness at room temperature. The residue obtained was of slight amount and was found to be entirely amorphous. The material was redissolved in 25 c. c. of acetic ether and the solution permitted to concentrate to dryness in a refrigerator. Despite this very gradual evaporation the same result was obtained.

In carrying out a further experiment 50 grams of the dry and finely divided excrement were placed in a paper coil and subjected to constant extraction with hot 95 per cent alcohol under a reflex condenser. This process was continued until no additional pigment was removed from the material. The extract was then concentrated to the condition of a thick sirupy liquid and until no further odor of alcohol could be appreciated. The residue was now twice extracted with boiling ether for the removal of fat. The ether-extracted material was covered with 50 c. c. of 95 per cent alcohol and warmed. It was filtered, sulphuric acid was added to very slight excess and the fluid was left to concentrate gradually at room temperature. A separation of amorphous material appeared, which increased with the decrease in volume. The separated substance was repeatedly examined for crystalline material, but with negative results. The dry residue was treated with three successive 25 c. c. portions of acetic ether. These combined extracts were distilled to a volume of 25 c. c. and the residual fluid left to evaporate. The slight amount of residue obtained failed to show any crystals of hippuric acid. Hence our examinations confirm the statements of Jaffé and Bongers, that the excrement of the fowl contains no hippuric acid.

Ornithuric acid.—Jaffé's method, a little modified, was applied to several 50-gram samples of the grain excrement, as follows: Constant extraction with hot 95 per cent alcohol was carried out in a paper coil for five hours. The alcohol was distilled from the extract and fat removed from the residue by means of ether. The next procedure consisted in extracting the residue with 100 c. c. of boiling absolute alcohol, a small fraction of the material resisting solution. This was collected on a small filter, the filtrate placed on the steam bath, and the alcohol driven off. The residual material was stirred in 50 c. c. of water and slightly acidified with sulphuric acid. Extraction with three successive 50 c. c. portions of ether was performed and the combined extracts distilled to small volume. On gradual evaporation of the residual ether there remained behind an amorphous residue in small quantity. Jaffé noted ornithuric acid in such an ethereal extract. The fluid exhausted by ether was covered and left to stand in a refrigerator for the possible deposition of ornithuric acid. After an interval of six weeks microscopic examination failed to reveal the presence of any crystalline material. Two weeks later a few needle-like crystals were noted, but the quantity was too slight to permit of purification or the application of any tests. Two weeks later still, the

amount was unchanged. Several examinations of the character just recorded gave uniformly negative results. Ornithuric acid appears to be excreted only after a diet containing certain benzoyl compounds.

Benzoic acid.—During the course of the examination of a large quantity of ether extract from the excrement, an odor strongly suggesting the oil of bitter almonds was noted. The odor, however, disappeared on standing over night. No benzoic acid could be demonstrated in the ether extract. Fifty grams of finely ground excrement were covered with 300 c. c. of water, acidified slightly with hydrochloric acid. Distillation with steam was now undertaken until 200 c. c. of fluid had passed over. The distillate presented a film of fatty-like material on the surface, in all probability fatty acid. The solution was shaken several times with ether and the combined extracts evaporated to dryness at ordinary temperature. The slight residue obtained displayed no evidence of benzoic acid.

Creatinin.—Reference is made on page 82 to a negative attempt to demonstrate the presence of creatinin. Another procedure was carried out. Fifty grams of material were continuously extracted with hot 95 per cent alcohol for five hours. The extract having been heated over the steam bath to remove the alcohol, the residue was treated with ether to remove fat, and the ethereal extract was filtered off. The residue remained largely insoluble on being rubbed up in 50 c. c. of boiling water. Filtration was conducted and one-half cubic centimeter of an acid-free 30 per cent solution of ZnCl_2 was added to the clear filtrate. The preparation was examined from time to time for the possible formation of crystals of creatinin zinc chloride. After standing in the refrigerator for a period of two months there was no indication of a crystalline formation, although a small amount of amorphous material had precipitated. Two further examinations with 50-gram samples of grain excrement were carried out, using the same method, but no evidence of the presence of creatinin could be obtained with the amounts of material employed. If present, its content must be extremely small.

Allantoin.—In view of a number of considerations the presence of allantoin in the urine of the bird would not seem unexpected. Thus, there is a close chemical relationship between this body and uric acid, for the oxidation of uric acid with potassium permanganate under appropriate conditions leads to the production of allantoin. Then the appearance of allantoin in the urine of the dog or cat is associated with conditions of diet when the output of uric acid is greatly augmented. Thus Minkowski¹⁷ demonstrated a ready production of allantoin in dogs on feeding thymus gland, which enormously increases uric acid elimination, and Salkowski¹¹⁸ reported a similar observation on administering large amounts of pancreas. The writer¹¹⁹ found that similar results hold true for the cat. The ingestion of uric acid as

such led to a pronounced excretion of allantoin in both these classes of animals. These observations, taken collectively, strongly point to the conclusion that allantoin represents an intermediate stage in the physiological oxidation of uric acid to urea.

Allantoin is readily soluble in hot 95 per cent alcohol, but less so in absolute alcohol. In ether it is practically insoluble. It gradually separates in characteristic crystalline form from an alcohol solution on standing. Hot water dissolves it readily, cold water with difficulty. In view of its solubility in hot alcohol the writer looked for the separation of this body from the alcoholic extracts of the grain excrement prepared in connection with the examination for hippuric acid and creatinin, but under those circumstances was unable to detect it. A further endeavor was made to locate this substance. Two samples of excrement, weighing 50 grams each, were rendered fat-free in a continuous extraction apparatus. The two lots of material were then submitted to constant extraction with hot 95 per cent alcohol for five hours. The two alcoholic extracts were united, distilled until reduced to a volume of about 100 c. c., and then exposed to the air to provide for gradual evaporation. A precipitation of amorphous material occurred, but no crystalline substance could be detected. The residue was extracted with absolute alcohol, the insoluble portion filtered off, and the clear filtrate left to stand. The gradual separation of amorphous matter again occurred, and frequent microscopic examinations failed to reveal the presence of any crystalline separation. The dry residue in all probability contains urea crystals, and it is possible that the large quantity of dark amorphous material present would obscure the appearance of a small quantity. This residue was extracted with petroleum ether, and, on evaporation of the reagent, a few long needle-like crystals were deposited. The quantity was not sufficiently large to establish their identity. In view of these apparently negative results it would be of interest to inquire regarding the possible production of allantoin after feeding nuclein-rich foods to fowls.

Kynurenin acid.—The writer also considered the possibility of kynurenin acid excretion by fowls. Among mammals this substance seems to be limited to the urine of dogs, and is closely associated with the metabolism of proteid matter.¹³ It is of additional interest from the fact that, aside from a certain constituent of the urine of the skunk, it is the only quinoline derivative reported as normally found in the urine of mammals. It appeared of interest to ascertain whether birds excrete this substance. With this end in view the following procedure was carried out: Fifty grams of the ground grain excrement were extracted with 400 c. c. of cold water. The aqueous infusion was filtered, evaporated to a volume of about 100 c. c., permitted to cool, and repeatedly filtered until clear. Jaffé's bromine test was repeatedly applied, but no bromine precipitate resulted. Search was also made

for this body by the use of Capaldi's¹²⁰ method. Twenty-five grams of the material were thoroughly stirred with 300 c. c. of 50 per cent ammonia. The filtered ammoniacal extract was treated with sufficient barium chloride to make the solution of 10 per cent strength. The mixture was filtered and the filtrate made acid with hydrochloric acid. Kynurenic acid, if present, should be deposited after standing from sixteen to twenty-four hours. A mere trace of amorphous material separated, and no change ensued on standing for a period of two weeks. This result was confirmed by a second trial, when a larger amount of excrement was employed. Kynurenic acid, then, would seem to be absent from the excrement.

Cholesterin-like material.—In the endeavor to demonstrate the presence of cholesterin-like material in the excrement, the ether extract of 50 grams of finely divided dung from the grain experiment was transferred to a small beaker and carefully saponified over the water bath with an alcoholic potash solution. The alcohol was gradually driven off and the residue taken up with 150 c. c. of water. The solution was transferred to a separatory funnel and thoroughly shaken with ether, a few drops of alcohol being added to facilitate the separation of the ether. This ethereal extraction was twice repeated and the combined extracts distilled until reduced to a volume of 25 c. c. Evaporation to dryness was then allowed to proceed in a refrigerator. A large crop of crystals was obtained, which, on microscopic examination, proved to be largely made up of flat, six-sided plates. No crystals of the notched appearance so characteristic of true cholesterin were noted. A few clusters of delicate needles were also scattered about. The material was then dissolved in absolute alcohol and the substance recrystallized from this medium. The crystals in this case presented the same general appearance as in the ethereal residue. The reaction of Salkowski was now applied and a positive result obtained. The two forms of crystals observed in the ether extract of the saponification mixture suggest the presence of different types of cholesterin.

The excrement from pure meat feeding was also examined for cholesterin-like material. One hundred grams of finely chopped ground substance were extracted with cold ether, the ethereal extract distilled off, the residue saponified and treated as described above for the grain excrement. A considerable quantity of crystalline material was obtained, which was twice purified. The crystals presented the appearance of minute six-sided plates, but none of needle-shaped form could be detected. The Salkowski test was readily obtained. By analogy from its presence in mammals this cholesterin-like substance is probably derived from the bile. The corresponding material obtained from the grain excrement is presumably to be ascribed to the food and bile, as corn and oats contain a form of cholesterin which is designated as phytosterin. The quantitative estimation of the cholesterin of the excrement is desirable with a view to its cor-

rective application in the determination of fat, a matter which we have referred to on page 41.

An amorphous organic alcohol-soluble substance.—It was observed that the alcoholic extracts of the excrement contained a large amount of amorphous material. The great bulk of it separated in the form of minute globules seemingly of uniform appearance. A sufficient quantity for manipulation was collected and examined. It dissolved readily in the alkali hydrates and ammonia, from which solutions it was precipitated in flocculent condition by mineral or acetic acids. It appeared to be insoluble in ether, benzol, chloroform, and water. The addition of water or ether to the alcoholic solution precipitated the substance in finely divided condition. Absolute alcohol takes it into solution, but much less readily than the same reagent of 95 per cent strength. The material is not hygroscopic, but dries readily in the open air and may be ground to a powder. It holds its pigment tenaciously and we have found no means as yet to remove a sufficient amount of it. Animal charcoal proved ineffective, and ether, benzol, and chloroform were unavailing. Purification of the material was attempted by repeated solution in ammonia, filtration and precipitation by the addition of hydrochloric acid. An analysis for nitrogen yielded a content of 10.41 per cent. None of the proteid color tests could be applied to the substance, owing to the large amount of associated pigment. The fact of the solubility of the material in alcohol excludes it from the class of albumins, globulins, or nucleins. It corresponds most closely to the class of proteid bodies found in corn and oats known as the zeins.

Chittenden and Osborn⁶⁵ report this body as soluble in alcohol of 61 to 91 per cent strength and containing 16.13 per cent nitrogen. While the content of nitrogen is much lower in the writer's preparation, it must be remembered that it is much more difficult to obtain the pure material from the excrement than from the grain, and some chemical changes may have occurred in its passage through the alimentary tract.

It should be noted in this connection that Szumowski⁶⁶ has recently made some additional observations on the chemico-physiological properties of zein. He claims that the substance is insoluble in absolute alcohol, whereas the preparation described by us is quite soluble in this reagent. Associated impurity or chemical change in digestion may be partially accountable for this difference.

We have referred at a former place to his studies relative to the peptic and tryptic digestion of zein. We have applied digestion tests to this alcohol-soluble body. One-half gram of the substance was treated with 50 c. c. of 0.2 per cent HCl containing 1 per cent of active Merck pepsin. At the end of a digestion period of forty-eight hours at 38° to 40° C. the amount of insoluble material seemed unchanged. A slight quantity of pigment had entered solution. The

filtrate from this fluid was treated with an equal volume of 95 per cent alcohol. A small amount of precipitate resulted, which was filtered off and tested with Millon's reagent with a positive result. This may be attributed, at least in part, to the trace of proteid associated with the pepsin preparation. The digestion was continued for one week with apparently little or no change in the quantity of the substance being acted upon. The filtrate was treated with 95 per cent alcohol as before, with a resultant precipitate rather larger than observed for the first digestion fluid. It responded to both the biuret and Millon's tests. It is planned to further examine this substance in the near future.

Further experiments on the digestibility of poultry foodstuffs are now in progress.

SUMMARY.

The provisional conclusions arrived at by these experiments may be presented as follows, it being recalled that but one experiment was completed with wheat:

(1) Corn, oats, and wheat show marked differences in the digestibility of several of their respective nutrients.

(2) The crude proteid and nitrogen-free extract are assimilated in much greater proportion in corn than in oats. The digestion coefficient for the crude proteid of wheat is intermediate in value between the average results for these two grains.

(3) The availability of the crude fat of corn is slightly greater than that of oats.

(4) The digestibility of the crude fat of wheat is conspicuously less than that of corn and oats; this fact may at least in part account for the untoward results of a sole wheat diet.

(5) Chickens consume a much greater quantity of corn than oats—an important fact to be kept in mind in a comparison of the digestion coefficients of the two grains.

(6) The nutritive superiority of corn over oats is indicated by the body weight. An increase is manifested under the use of corn while a tendency in the opposite direction is seen with oats.

(7) The nutrients of corn are fed at a lower cost than those of oats and wheat. The last-named grain is the most costly of the three foods. This conclusion is based on the actual availability of the various nutrients of the grains.

(8) Regarding the application of these grains in mixed dietaries the following suggestions are offered: Corn may be included for the main nutrients, that is, crude proteid, nitrogen-free extract, and ether extract. Oats may be utilized for the crude proteid and ether extract. Wheat may be employed for the crude proteid and nitrogen-free extract, but adequate provision must be made for the deficient yield of this grain in fat.

[illegible]

TABLE II.—*Daily consumption of food and water, weight of excrement, etc.*—Continued.

	Oats, chicken B ² . (Duration, Jan. 4-12, inclusive.)				Oats, chicken E. (Duration, Mar. 4-11, inclusive.)				Oats, chicken F. (Duration, Mar. 4-11, inclusive.)			
	Air-dried food consumed.	Air-dried excrement.	Water consumed.	Body weight.	Air-dried food consumed.	Air-dried excrement.	Water consumed.	Body weight.	Air-dried food consumed.	Air-dried excrement.	Water consumed.	Body weight.
First day.....	<i>Gms.</i> 60.0	<i>Gms.</i> 26.8	<i>c.c.</i> 118	<i>Lbs. oz.</i> 3 3	<i>Gms.</i> 49.4	<i>Gms.</i> 24.0	<i>c.c.</i> 82	<i>Lbs. oz.</i> 3 7	<i>Gms.</i> 31.3	<i>Gms.</i> 11.8	<i>c.c.</i> 58	<i>Lbs. oz.</i> 2 3 $\frac{1}{4}$
Second day.....	60.0	30.5	66	3 2 $\frac{1}{2}$	49.4	23.9	76	3 7 $\frac{1}{2}$	28.7	11.3	54	2 3 $\frac{1}{4}$
Third day.....	60.0	29.4	92	3 2 $\frac{1}{2}$	49.9	25.6	81	3 6 $\frac{1}{2}$	30.0	12.5	53	2 3 $\frac{1}{4}$
Fourth day.....	60.6	26.5	100	3 2 $\frac{1}{2}$	48.9	22.8	88	3 6	32.5	13.4	55	2 2 $\frac{1}{4}$
Fifth day.....	60.0	30.1	92	3 3	49.3	24.0	73	3 6 $\frac{1}{2}$	28.8	12.5	49	2 2 $\frac{1}{4}$
Sixth day.....	60.6	34.5	96	3 2 $\frac{1}{2}$	49.5	26.0	82	3 6 $\frac{1}{2}$	21.8	12.1	30	2 1 $\frac{1}{4}$
Seventh day.....	60.3	31.9	81	3 3	49.3	21.0	65	3 5	23.6	12.2	40	2 1
Eighth day.....	60.3	29.8	66	3 3 $\frac{1}{4}$	49.0	30.8	68	3 5	22.9	10.6	42	2 1
Ninth day.....	60.6	34.3	82	3 3 $\frac{1}{4}$								

	Oats, chicken A ² . (Duration, Dec. 29-Jan. 5, inclusive.)				Oats, chicken H. (Duration, July 15-23, inclusive.)			
	Air-dried food consumed.	Air-dried excrement.	Water consumed.	Body weight.	Air-dried food consumed.	Air-dried excrement.	Water consumed.	Body weight.
First day.....	<i>Gms.</i> 54.6	<i>Gms.</i> 23.2	<i>c.c.</i> 102	<i>Lbs. oz.</i> 3 9 $\frac{1}{4}$	<i>Gms.</i> 36.0	<i>Gms.</i> 12.1	<i>c.c.</i> 64	<i>Lbs. oz.</i> 3 3 $\frac{1}{4}$
Second day.....	52.8	15.1	90	3 9	35.1	14.6	44	3 2
Third day.....	54.1	28.9	97	3 8 $\frac{1}{4}$	38.2	19.4	56	3 3
Fourth day.....	54.2	31.7	98	3 8 $\frac{1}{4}$	39.5	15.1	35	3 2 $\frac{1}{4}$
Fifth day.....	54.5	31.5	97	3 8 $\frac{1}{4}$	39.0	14.6	50	3 2
Sixth day.....	54.4	24.0	82	3 8	38.8	18.0	57	3 2
Seventh day.....	49.8	30.9	81	3 8	39.4	14.6	47	3 1
Eighth day.....	46.9	26.7	75	3 7 $\frac{1}{4}$	39.3	16.6	57	3 1
Ninth day.....					39.4	18.4	52	3 1

	Beef, chicken M. (Duration, Apr. 15-20, inclusive.)				Beef, chicken N. (Duration, Apr. 15-20, inclusive.)			
	Fresh beef consumed.	Air-dried excrement.	Water consumed.	Body weight.	Fresh beef consumed.	Air-dried excrement.	Water consumed.	Body weight.
First day.....	<i>Gms.</i> 25	<i>Gms.</i> 8.8	<i>c.c.</i> 42	<i>Lbs. oz.</i> 3 5	<i>Gms.</i> 25	<i>Gms.</i> 8.0	<i>c.c.</i> 52	<i>Lbs. oz.</i> 3 7
Second day.....	25	13.0	43	3 4 $\frac{1}{4}$	25	8.7	43	3 7
Third day.....	25	8.0	48	3 4	25	7.9	46	3 6 $\frac{1}{4}$
Fourth day.....	25	6.8	43	3 3	25	8.7	39	3 6
Fifth day.....	25	8.7	37	3 5 $\frac{1}{4}$	25	9.4	44	3 5 $\frac{1}{4}$
Sixth day.....	25	6.5	40	3 5 $\frac{1}{4}$	25	9.0	41	3 5 $\frac{1}{4}$

TABLE III.—*Composition of the food.*

AIR-DRIED.

	Corn.		Wheat.	Oats.		Meat.
	Sample 1.	Sample 2.		Sample 1.	Sample 2.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Moisture	11.33	11.14	9.53	8.29	9.12	7.06
Crude proteid.....	9.80	9.44	11.34	12.03	14.90	79.25
Crude fiber.....	2.05	2.16	1.59	10.25	9.75	.....
Ether extract.....	5.15	5.24	2.05	4.69	3.71	4.72
Ash	1.32	1.30	1.84	3.10	3.55	3.11
Nitrogen-free extract.....	70.35	70.72	73.65	61.64	58.97	.....
Starch	60.06	60.18	55.83	37.05	.....	.....
Sucrose	1.17	1.72	2.71	1.54	.....	.....
Dextrose.....	1.07	.86	.76	1.43	.....	.....
Pentosans.....	5.35	5.96	7.64	13.47	.....	.....
Total nitrogen	1.57	1.51	1.81	1.92	2.38	12.87
Peptone nitrogen .....	.....	.....	.....	.....	.....	.17
Nitrogen of meat-bases and gelatinoids.....	.....	.....	.....	.....	.....	.19
Organic matter .....	.....	.....	.....	.....	.....	96.89

WATER-FREE.

Crude proteid.....	11.05	10.62	12.53	13.11	16.40	85.27
Crude fiber	2.31	2.43	1.76	11.18	10.73	.....
Ether extract	5.81	5.89	2.26	5.11	4.08	5.08
Ash	1.49	1.46	2.03	3.38	3.91	3.34
Nitrogen-free extract	79.34	79.58	81.41	67.21	64.89	.....
Starch	67.74	67.72	61.71	40.39	.....	.....
Sucrose	1.32	1.93	2.99	1.68	.....	.....
Dextrose.....	1.21	.97	.84	1.56	.....	.....
Pentosans.....	6.03	6.71	8.44	14.69	.....	.....
Total nitrogen	1.77	1.70	2.00	2.09	2.62	13.84
Peptone nitrogen .....	.....	.....	.....	.....	.....	.18
Nitrogen of meat-bases and gelatinoids.....	.....	.....	.....	.....	.....	.20
Organic matter .....	.....	.....	.....	.....	.....	96.66

^aThe moisture of the pressed meat fed was 66.56 per cent.

TABLE IV.—*Composition of the excrement (air-dried).*

	Corn. Chicken A ¹ .	Corn. Chicken B ¹ .	Corn. Chicken C ¹ .	Corn. Chicken D.	Corn. Chicken G.	Wheat. Chicken A ⁴ .	Oats. Chicken A ² .	Oats. Chicken A ³ .
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Moisture	4.04	3.75	4.70	6.02	7.09	4.17	5.25	3.69
Total nitrogen	6.12	6.72	7.62	4.74	6.64	6.12	3.42	3.12
Uric acid nitrogen ..	3.50	4.50	4.72	2.78	3.59	3.73	1.79	1.80
Ammonia nitrogen ..	.96	1.04	1.13	.94	1.33	.65	.53	.48
Crude proteid	10.37	7.37	11.06	6.37	10.75	10.87	6.87	5.25
Ether extract	4.79	3.89	4.10	3.60	6.34	3.58	1.76	1.60
Crude fiber	11.16	9.20	8.83	10.40	13.66	11.23	18.92	18.51
Total ash	11.16	14.46	8.70	23.07	8.10	23.48	19.31	29.20
N.-free extract	46.80	46.56	47.07	41.05	41.66	34.67	41.88	35.76
Pentosans	20.47	.....	26.23	20.96	.....	.....	20.52	21.95
Uric acid	10.52	13.51	14.17	8.35	10.79	11.21	5.37	5.41
Ammonia	1.16	1.26	1.37	1.14	1.61	.79	.64	.58
Pure ash	7.40	6.65	3.48	12.99	7.53	15.93	4.46	7.09
Total SiO ₂	3.76	7.81	5.22	10.08	.57	7.55	14.85	22.11

	Oats. Chicken B ² .	Oats. Chicken C ² .	Oats. Chicken C ³ .	Oats. Chicken E.	Oats. Chicken F.	Oats. Chicken H.	Meat. Chicken M.	Meat. Chicken N.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Moisture	4.76	3.91	3.24	3.83	5.02	6.71	3.18	2.71
Total nitrogen	3.91	3.89	3.49	4.35	5.54	6.13	26.09	26.37
Uric acid nitrogen ..	2.26	2.23	2.21	2.60	3.33	3.45	18.97	19.33
Ammonia nitrogen ..	.56	.54	.55	.65	.72	1.01	2.31	2.40
"Residual" nonpro- teid nitrogen .....	.....	.....	.....	.....	.....	.....	2.06	2.11
Crude proteid	6.81	7.00	4.56	6.87	9.31	10.43	17.18	15.81
Ether extract	2.12	2.13	1.33	1.63	2.10	1.74	1.36	1.39
Crude fiber	20.31	18.25	18.20	20.50	23.38	21.52	.....	.....
Total ash	24.66	18.59	33.22	21.27	7.72	8.83	.....	.....
N.-free extract	33.87	42.77	32.13	37.31	41.60	39.19	.....	.....
Pentosans	24.11	25.24	21.05	24.27	26.75	.....	.....	.....
Uric acid	6.79	6.70	6.65	7.80	10.00	10.36	56.91	57.99
Ammonia	.68	.65	.67	.79	.87	1.22	2.80	2.91
Pure ash	4.09	7.35	4.74	3.89	3.74	4.82	9.56	8.54
Total SiO ₂	20.57	11.24	28.48	17.38	3.98	4.01	.92	.88

TABLE V.—Composition of the excrement (H_2O and silica-free).

	Corn. Chicken A ¹ .	Corn. Chicken B ¹ .	Corn. Chicken C ¹ .	Corn. Chicken D.	Corn. Chicken G.	Wheat. Chicken A ¹ .	Oats. Chicken A ² .	Oats. Chicken A ³ .
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Total nitrogen	6.64	7.60	8.45	5.65	7.19	6.93	4.28	4.20
Uric acid nitrogen ..	3.80	5.09	5.24	3.31	3.89	4.23	2.24	2.43
Ammonia nitrogen ..	1.04	1.17	1.25	1.12	1.44	.74	.66	.65
Crude proteid	11.25	8.33	12.28	7.59	11.64	12.32	9.61	7.07
Ether extract	5.19	4.39	4.55	4.29	6.86	4.05	2.20	2.15
Crude fiber	12.10	10.40	9.80	12.39	14.79	12.72	23.68	24.95
Ash	8.02	7.52	3.86	15.48	8.15	18.04	5.58	9.55
N.-free extract	50.76	52.64	52.25	48.93	45.11	39.27	52.45	48.20
Pentosans	22.20	.....	29.12	24.98	.....	.....	25.68	29.58
Uric acid	11.41	15.28	15.73	9.95	11.68	12.70	6.72	7.29
Ammonia	1.26	1.42	1.52	1.36	1.75	.90	.80	.79

	Oats. Chicken B ² .	Oats. Chicken C ² .	Oats. Chicken C ³ .	Oats. Chicken E.	Oats. Chicken F.	Oats. Chicken H.	Meat. Chicken M.	Meat. Chicken N.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Total nitrogen	5.23	4.58	5.11	5.52	6.09	6.86	27.20	27.35
Uric acid nitrogen ..	3.03	2.63	3.24	3.30	3.66	3.86	19.78	20.05
Ammonia nitrogen ..	.75	.63	.80	.82	.78	1.13	2.41	2.49
"Residual" nonpro- teid nitrogen .....	.....	.....	.....	.....	.....	.....	2.14	2.19
Crude proteid	9.12	8.25	6.67	8.71	10.23	11.68	17.91	16.39
Ether extract	2.83	2.51	1.94	2.06	2.30	1.95	1.42	1.45
Crude fiber	27.20	21.51	26.65	26.02	25.69	24.10	.....	.....
Ash	5.48	8.66	6.94	4.94	4.11	5.40	9.97	8.85
N.-free extract	45.36	50.41	47.06	47.38	45.71	43.89	.....	.....
Pentosans	32.29	29.75	30.83	30.81	29.39	.....	.....	.....
Uric acid	9.09	7.89	9.74	9.90	10.99	11.60	59.34	60.15
Ammonia	.91	.76	.97	.99	.95	1.37	2.92	3.02

TABLE VI.—Digestion experiments with corn.^a

CHICKEN A ¹ .—CORN.					CHICKEN B ¹ .—CORN.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter ..	1,130.30	144.30	986.00	87.23	Organic matter ..	382.05	52.13	329.92	86.34
Crude proteid ...	126.80	20.46	106.34	83.36	Crude proteid ...	42.87	5.73	37.14	86.63
Ether extract ...	66.64	9.45	57.19	85.82	Ether extract ...	22.53	3.02	19.51	86.59
Crude fiber	26.53	22.02	4.51	17.00	Crude fiber.....	8.96	7.15	1.81	20.19
Nitrogen-free extract.....	910.30	92.34	817.96	89.85	Nitrogen-free extract.....	307.70	36.21	271.49	88.23
Pentosans	69.23	40.39	28.84	41.66	Pentosans .....	.....	.....	.....	.....
Duration of experiment.....days.. 13					Duration of experiment days.. 6				
Sand consumed.....grams.. 8.6					Water consumed grams.. 599				
Water consumed do.... 985					Gain in weight.....ounces.. 0.75				
Gain in weight ounces.. 7.5					Ratio H ₂ O to dry matter..... 1 to 0.647				
Ratio H ₂ O to dry matter 1 to 1.164					NOTE.—Sand and marble consumed ad libitum, but amounts not observed.				
Ratio sand to dry matter 1 to 133.9									

^a See chart at back of bulletin for graphic record of digestion coefficients.

TABLE VI.—*Digestion experiments with corn*—Continued.

CHICKEN C ¹ .—CORN.					CHICKEN D.—CORN.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	429.61	61.14	368.47	85.77	Organic matter..	679.03	89.00	590.03	86.89
Crude proteid...	48.20	9.51	38.69	80.27	Crude proteid...	73.21	9.23	63.98	87.39
Ether extract...	25.33	3.52	21.81	86.01	Ether extract...	40.64	5.21	35.43	87.18
Crude fiber.....	10.08	7.59	2.49	24.70	Crude fiber.....	16.75	15.07	1.68	10.03
Nitrogen-free extract.....	346.00	40.50	305.50	88.29	Nitrogen-free extract.....	548.40	59.48	488.92	89.15
Pentosans.....	26.31	22.57	3.74	14.21	Pentosans.....	46.22	30.37	15.85	34.29
Duration of experiment.....days.. 6					Duration of experiment.....days.. 8				
Water consumed.....grams.. 398					Sand consumed.....grams.. 28.09				
Loss in weight.....ounces.. 0.25					Water consumed.....do.... 720				
Ratio H ₂ O to dry matter..... 1 to 1.10					Gain in weight.....ounces.. 4				
NOTE.—Sand and marble consumed ad libitum, but amounts undetermined.					Ratio H ₂ O to dry matter..... 1 to 0.956				
					Ratio sand to dry matter..... 1 to 24.52				
CHICKEN G.—CORN.					AVERAGE COEFFICIENTS, ALL CORN EXPERIMENTS.				
	Income.	Outgo.	Assimilation.	Coefficient.					
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>						
Organic matter..	391.84	50.87	340.97	87.02	Organic matter.....			86.65	
Crude proteid...	42.24	7.55	34.69	82.12	Crude proteid.....			83.95	
Ether extract...	23.44	4.44	19.00	81.05	Ether extract.....			85.32	
Crude fiber.....	9.66	9.59	0.07	0.72	Crude fiber.....			a [14.53]	
Nitrogen-free extract.....	316.50	29.26	287.24	90.75	Nitrogen-free extract.....			89.25	
Pentosans.....									
Duration of experiment.....days.. 9									
Water consumed.....grams.. 563									
Loss in weight.....ounces.. 1									
Ratio H ₂ O to dry matter..... 1 to 0.738									
NOTE.—No sand was consumed.									

^aSee page 59.

TABLE VII.—*Digestion experiments with oats,^a wheat, and meat.*

CHICKEN A ² .—OATS.					CHICKEN A ³ .—OATS.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	561.45	211.60	349.85	62.31	Organic matter .	373.48	133.40	240.08	64.28
Crude proteid ...	76.22	20.94	55.28	72.52	Crude proteid...	50.69	11.46	39.23	77.39
Ether extract....	29.72	5.36	24.36	81.96	Ether extract....	19.76	3.49	16.27	82.34
Crude fiber	64.94	57.67	7.27	11.19	Crude fiber.....	43.19	40.39	2.80	6.48
Nitrogen-free extract.....	390.60	127.60	263.00	67.33	Nitrogen-free extract.....	259.70	78.03	181.67	69.95
Pentosans	85.35	62.54	22.81	26.72	Pentosans.....	56.76	47.89	8.87	15.63
Duration of experiment.....days.. 11					Duration of experiment.....days.. 8				
Sand consumed.....grams.. 31.92					Sand consumed.....grams.. 52.1				
Water consumed.....do.... 1,056					Water consumed.....do.... 757				
Gain or loss in weight..... None.					Loss in weight.....ounces.. 1.75				
Ratio H ₂ O to dry matter..... 1 to 0.55					Ratio H ₂ O to dry matter..... 1 to 0.510				
Ratio sand to dry matter..... 1 to 18.74					Ratio sand to dry matter..... 1 to 0.742				
CHICKEN B ² .—OATS.					CHICKEN C ² .—OATS.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	480.89	155.80	325.09	67.60	Organic matter .	298.97	118.75	180.22	60.28
Crude proteid ...	65.29	16.82	48.47	74.24	Crude proteid...	40.59	11.85	28.74	70.80
Ether extract....	25.45	5.23	20.22	79.45	Ether extract....	15.83	3.61	12.22	77.19
Crude fiber	55.62	50.17	5.45	9.80	Crude fiber.....	34.58	30.90	3.68	10.64
Nitrogen-free extract.....	334.50	83.62	250.88	74.99	Nitrogen-free extract.....	208.00	72.41	135.59	65.19
Pentosans	73.10	59.56	13.54	18.52	Pentosans.....	45.45	42.73	2.72	5.98
Duration of experiment.....days.. 9					Duration of experiment.....days.. 8				
Sand consumed.....grams.. 31.5					Water consumed.....grams.. 563				
Water consumed.....do.... 828					Loss in weight.....ounces.. 2				
Gain in weight.....ounces.. 0.25					Ratio H ₂ O to dry matter..... 1 to 0.549				
Ratio H ₂ O to dry matter..... 1 to 0.601					NOTE.—Sand offered ad libitum, but amount consumed was undetermined.				
Ratio sand to dry matter..... 1 to 15.81									

^aSee chart at back of bulletin for graphic record of digestion coefficients.

TABLE VII.—*Digestion experiments with oats, wheat, and meat—Continued.*

CHICKEN C ³ .—OATS.					CHICKEN E.—OATS.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	271.32	88.43	182.89	67.41	Organic matter..	349.88	125.30	224.58	64.18
Crude proteid...	36.84	7.17	29.67	80.53	Crude proteid...	47.49	12.99	34.50	72.65
Ether extract....	14.36	2.09	12.27	85.44	Ether extract...	18.52	3.08	15.44	83.36
Crude fiber.....	31.39	28.63	2.76	8.79	Crude fiber.....	40.47	38.75	1.72	4.25
Nitrogen-free extract.....	188.70	50.54	138.16	73.21	Nitrogen-free extract.....	243.40	70.51	172.89	71.03
Pentosans.....	41.24	33.11	8.13	19.71	Pentosans.....	53.18	45.87	7.31	13.74
Duration of experiment.....days..				7	Duration of experiment.....days..				8
Sand consumed.....grams..				64.38	Sand consumed.....grams..				27.44
Water consumed.....do....				446	Water consumed.....do....				615
Loss in weight.....ounces..				2.50	Loss in weight.....ounces..				2
Ratio H ₂ O to dry matter.....				1 to 0.629	Ratio H ₂ O to dry matter.....				1 to 0.588
Ratio sand to dry matter.....				1 to 4.39	Ratio sand to dry matter.....				1 to 13.19
CHICKEN F.—OATS.					CHICKEN H.—OATS.				
	Income.	Outgo.	Assimilation.	Coefficient.		Income.	Outgo.	Assimilation.	Coefficient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	194.59	69.86	124.73	64.10	Organic matter..	301.03	103.50	197.53	65.62
Crude proteid...	26.42	8.51	17.91	67.75	Crude proteid...	51.36	14.81	36.55	71.16
Ether extract....	10.30	1.92	8.38	81.35	Ether extract....	12.79	2.47	10.32	80.68
Crude fiber.....	22.51	21.38	1.13	5.02	Crude fiber.....	33.61	30.56	3.05	9.07
Nitrogen-free extract.....	135.40	38.04	97.36	71.90	Nitrogen-free extract.....	203.30	55.65	147.65	72.62
Pentosans.....	29.58	24.46	5.12	17.31	Pentosans.....				
Duration of experiment.....days..				8	Duration of experiment.....days..				9
Sand consumed.....				None.	Sand consumed.....				None.
Water consumed.....grams..				339	Water consumed.....grams..				462
Loss in weight.....ounces..				2.25	Loss in weight.....ounces..				2.50
Ratio H ₂ O to dry matter.....				1 to 0.594	Ratio H ₂ O to dry matter.....				1 to 0.678
CHICKENS A ² AND A ³ .—OATS. COMBINED COEFFICIENT.					CHICKENS A, B, C, E, F, AND H.—OATS. COMBINED COEFFICIENT.				
Organic matter.....				63.29	Organic matter.....				64.77
Crude proteid.....				74.95	Crude proteid.....				73.38
Ether extract.....				82.15	Ether extract.....				81.48
Crude fiber.....				8.83	Crude fiber.....				8.15
Nitrogen-free extract.....				68.69	Nitrogen-free extract.....				70.77
Pentosans.....				21.17					
CHICKENS C ² AND C ³ .—OATS. COMBINED COEFFICIENT.									
Organic matter.....				63.84					
Crude proteid.....				75.66					
Ether extract.....				81.81					
Crude fiber.....				9.71					
Nitrogen-free extract.....				69.20					
Pentosans.....				12.84					

TABLE VII.—*Digestion experiments with oats, wheat, and meat*—Continued.

CHICKEN A ⁴ .—WHEAT.					CHICKEN M.—MEAT DIET.				
	Income.	Outgo.	Assimi- lation.	Coeffi- cient.		Income.	Outgo.	Assimi- lation.	Coeffi- cient.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	
Organic matter..	416.17	66.81	349.36	83.94	Organic matter..	96.97	12.35	84.62	87.26
Crude proteid...	53.24	12.03	41.21	77.40	Crude proteid...	85.54	8.63	76.91	89.91
Ether extract....	9.62	3.96	5.66	58.83	Ether extract...	5.09	.68	4.41	86.59
Crude fiber.....	7.46	12.43	—4.97	.....	Crude fiber.....				.....
Nitrogen-free ex- tract.....	345.80	38.38	307.42	88.90	Nitrogen-free extract.....				.....
Duration of experiment..... days..				8	Duration of experiment..... days..				6
Sand consumed..... grams..				52.1	Sand consumed.....				None.
Water consumed..... do... ..				722	Water consumed..... grams..				253
Loss in weight..... ounces..				1	Gain in weight..... ounce..				0.5
Ratio H ₂ O to dry matter.....				1 to 0.588	Ratio H ₂ O to dry matter.....				1 to 0.396
Ratio sand to dry matter.....				1 to 8.15					
CHICKEN N.—MEAT DIET.					CHICKENS M AND N.—AVERAGE COEFFI- CIENTS.				
	Income.	Outgo.	Assimi- lation.	Coeffi- cient.	Organic matter				87.05
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>		Crude proteid.....				90.20
Organic matter..	96.97	12.76	84.21	86.84	Ether extract.....				86.30
Crude prot-	85.54	8.11	77.43	90.51					
Ether extract....		.71	4.38	86.01					
Crude fiber.....				.....					
Nitrogen-free ex- tract.....				.....					
Duration of experiment..... days..				6					
Sand consumed.....				None.					
Water consumed..... grams..				265					
Loss in weight..... ounces..				1.5					
Ratio H ₂ O to dry matter.....				1 to 0.378					

TABLE VIII.—*Metabolic nitrogen of excrement.*

Subject.	Total nitrogen.	Extracted 95 per cent alcohol.	Extracted absolute alcohol.	Extracted ether extract.	Extracted acetic ether.	95 per cent alcohol, per cent of total nitrogen.	Absolute alcohol, per cent of total nitrogen.	Ether extract, per cent of total nitrogen.	Acetic ether, per cent of total nitrogen.	95 per cent alcohol, per cent of fecal nitrogen.	Ether extract, per cent of fecal nitrogen.	Acetic ether, per cent of fecal nitrogen.	Absolute alcohol, per cent of fecal nitrogen.
	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.
Chicken A ¹ ...	6.12	0.81	.....	0.098	.....	13.23	.....	1.60	.....	.....	.....	.....	.....
Chicken B ¹ ...	6.72	.83	.....	.12	.....	12.35	.....	1.78	.....	70.33	10.17	.....	.....
Chicken C ¹ ...	7.62	1.06	.....	.....	.....	13.91	.....	.....	.....	59.88	.....	.....	.....
Chicken D....	4.74	.60	.....	.10	0.10	12.65	.....	2.10	2.11	.....	.....	9.80	.....
Chicken A ⁴ ...	6.12	.51	.....	.12	.....	14.91	.....	1.96	.....	.....	9.80	.....	.....
Chicken A ² ...	3.42	.51	.....	.....	.....	14.91	.....	.....	.....	46.36	.....	.....	.....
Chicken A ³ ...	3.12	.43	.....	.10	.21	13.78	.....	3.20	6.73	.....	.....	25	.....
Chicken B ² ...	3.91	.50	.....	.12	.19	12.78	.....	3.07	4.85	.....	11.90	17.43	.....
Chicken C ² ...	3.89	.38	.....	.....	.....	9.77	.....	.....	.....	.....	11	.....	.....
Chicken C ³ ...	3.49	.60	.....	.....	.....	17.19	.....	.....	.....	.....	.....	.....	.....
Chicken E....	4.35	.36	0.35	.....	.....	8.98	8.04	.....	.....	.....	31.81	.....	31.81
Chicken F....	5.54	.....	.29	.....	.....	.....	5.14	.....	.....	.....	19.46	.....	19.46
Chicken M....	26.09	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chicken N....	26.37	.....	.93	.07	.....	.....	3.54	.....	.....	.....	2.65	.....	35.22

TABLE IX.—*Digestion coefficients of poultry and other farm animals compared.*

	Organic matter.	Crude proteid.	Ether extract.	Crud ^d fibre...	Nitrogen-free extract.
CORN, ETC.					
Poultry: Average of 5 experiments with corn (Brown).....	86.65	83.95	85.32	α [14.53]	89.25
Poultry: Average of 4 experiments with corn (Paraschtschuk) ⁵⁴	89.21	92.50	83.43	31.20	91.76
Poultry: Average of 3 experiments with corn (Fields & Ford) ⁵²	86.4	49.8	91.7	.....	92.5
Poultry: Average of 3 experiments with corn meal (Fields & Ford).....	85.5	48.4	93.1	.....	91.5
Poultry: Average of 3 experiments with Kafir corn (Fields & Ford).....	87.7	52.9	73.7	20.1	96.3
Poultry: Average of 3 experiments with Kafir corn meal (Fields & Ford).....	87.2	42.6	82.7	35.5	82.7
Ruminants: Average of 12 experiments with corn (Wolff) ⁹¹	91	72	85	77	94
Horses: Average of 2 experiments with corn (Wolff).....	89	77	61	70	94
Swine: Average of 4 experiments with corn (Wolff).....	92	86	76	40	95
OATS.					
Poultry: Average of 8 experiments (Brown).....	64.77	73.38	81.48	α [8.15]	70.77
Poultry: 1 experiment (Grost) ⁵¹.....	.....	62.34	84.01	.50	60.82
Ruminants: Average of 39 experiments (Wolff) ⁹¹ ...	70	78	83	20	76
Horses: Average of 8 experiments (Wolff).....	68	86	71	21	74

^a See page 59.

TABLE IX.—*Digestion coefficients of poultry and other farm animals compared*—Cont'd.

	Organic matter.	Crude proteid.	Ether extract.	Crude fiber.	Nitrogen- free ex- tract.
WHEAT.					
Poultry: 1 experiment (Brown)	83.94	77.40	58.83	.....	86.02
Poultry: Average of 2 experiments (Kalugin) ⁵⁰ ...	81.92	56.91	55.21	29.95	93.30
Poultry: 1 experiment (Lehmann) ⁵³	81.86	77.12	39.67	None.	86.59
Swine: 1 experiment (Snyder) ⁹⁶ .....	.....	70	60	30	74
PEAS.					
Poultry: Average of 2 experiments with peas (Kalugin) ⁵⁰	75.52	90.32	83.71	13.75	91.65
Poultry: 1 experiment with peas (Lehmann) ⁵³	78.62	83.68	76.31	.....	77.96
Ruminants: Average of 2 experiments with peas (Wolff) ⁹¹	90	89	75	66	93
Horses: 1 experiment with peas (Wolff)	80	83	9	8	89
Swine: Average of 10 experiments with peas (Wolff)	91	88	49	71	96
Poultry: Average of 3 experiments with cowpeas (Fields & Ford) ⁶²	71.5	40.5	88.7	18.4	87.1
Poultry: Average of 3 experiments with cowpea meal (Fields & Ford)	72.2	43.7	88.7	9.6	87.8
BARLEY.					
Poultry: Average of 2 experiments (Kalugin) ⁵⁰ ...	77.17	79.22	68.29	.....	89.07
Poultry: 1 experiment (Grost) ⁵¹ .....	.....	75.41	67.43	.20	81.11
Ruminants: Average of 4 experiments (Wolff) ⁹¹ ..	86	70	89	50	92
Horses: 1 experiment (Wolff)	87	80	42	100	87
Swine: Average of 8 experiments (Wolff)	82	76	65	15	90
RYE.					
Poultry: 1 experiment (Grost) ⁵¹ .....	.....	70.72	16.59	2.40	87.80
BUCKWHEAT.					
Poultry: Average of 2 experiments (Kalugin) ⁵⁰ ...	69.38	59.40	89.22	2.02	86.99
MILLET.					
Poultry: Average of 2 experiments (Kalugin) ⁴⁹ .....	.....	62.40	55.71	5.55	98.39
BEEF.					
Poultry: Average of 2 experiments (Brown)	87.05	90.20	86.30	.....	.....

TABLE X.—Feeding standards for poultry based on digestion coefficients.

I.—AMOUNT OF NUTRIENTS DAILY CONSUMED BY 100 POUNDS LIVE WEIGHT.

	Organic matter.	Crude proteid.	Ether extract.	Nitrogen- free extract.	Nutritive ratio.	Fuel value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>		<i>Calories.</i>
Hens (3 to 4 pounds), corn	4.83	0.53	0.28	3.89	1:8.6	100,732
Hens (3 to 4 pounds), oats	2.84	.37	.15	1.97	1:6.3	54,065
Hens (3 to 4 pounds), wheat	3.27	.42	.07	2.72	1:6.9	66,259

II.—AMOUNT OF NUTRIENTS DAILY ASSIMILATED BY 100 POUNDS LIVE WEIGHT.

Hens (3 to 4 pounds), corn	4.19	0.45	0.24	3.46	1: 9.0	88,623
Hens (3 to 4 pounds), oats	1.83	.28	.12	1.39	1: 6.0	39,438
Hens (3 to 4 pounds), wheat	2.70	.32	.04	2.42	1: 7.8	56,681
Oxen (at rest) ⁹¹		.07	.01	.80	1:11.8	.....
Cows (milk yield, 11 pounds) ⁹¹		.16	.03	1.00	1: 6.7	.....
Sheep (coarse wool) ⁹¹		.12	.02	1.05	1: 9.1	.....
Horses (light work) ⁹¹		.15	.04	.95	1: 7.0	.....
Cows (milk yield, 27½ pounds) ⁹¹		.33	.08	1.30	1: 4.5	.....
Oxen (severe work) ⁹¹		.28	.08	1.30	1: 5.3	.....
Horses (severe work) ⁹¹		.25	.08	1.33	1: 6.0	.....
Swine (fattening, third period) ⁹¹		.27	.04	1.80	1: 7.0	.....

III.—DIGESTIBLE NUTRIENTS PER DAY PER 100 POUNDS LIVE WEIGHT.^a

Capons (9 to 12 pounds)	2.30	0.30	0.20	1.74	1:7.5	46,000
Hens (3 to 5 pounds)	3.90	.50	.30	2.95	1:7.4	76,000
Hens (5 to 7 pounds)	2.70	.40	.20	2.00	1:6.2	53,000

IV.—AMOUNT OF ASSIMILATED NUTRIENTS IN 100 POUNDS OF THE GRAIN FED.

Corn	85.35	9.27	4.93	70.82	1:8.9	.....
Oats	62.58	9.62	4.16	47.56	1:6.0	.....
Wheat	82.23	9.63	1.33	70.03	1:7.5	.....

V.—COST OF 1 POUND OF THE ASSIMILATED NUTRIENTS OF THE GRAIN.^b

	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>		
Corn	1.41	1.44	1.46	1.39	.....	.....
Oats	2.32	2.17	1.93	2.25	.....	.....
Wheat	1.78	1.96	2.55	1.76	.....	.....

^a Feeding standard compiled by Wheeler.⁹⁶

^b With corn at 60 cents, oats at 40 cents, and wheat at 80 cents per bushel.

TABLE XI.—*Cost of the principal nutrients.^a*

	Experiments with corn.								
	Chicken A ¹ .			Chicken B ¹ .			Chicken C ¹ .		
	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Organic matter.....	3.0405	0.3881	2.6524	1.0277	0.1402	0.8875	1.1556	0.1645	0.9911
Crude proteid.....	.0380	.0061	.0319	.0128	.0017	.0111	.0144	.0028	.0116
Ether extract.....	.0106	.0015	.0091	.0036	.0005	.0031	.0040	.0006	.0034
Nitrogen-free extract....	1.9844	.2013	1.7831	.6707	.0789	.5918	.7542	.0883	.6659
Value of gain (+) or loss (−) in weight.....	+7.5			+.75			−.25		

	Experiments with corn.						Experiments with oats.		
	Chicken D ¹ .			Chicken G.			Chicken A ² .		
	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Organic matter.....	1.8145	0.2385	1.5760	1.0501	0.1363	0.9138	1.7405	0.6559	1.0846
Crude proteid.....	.0212	.0027	.0185	.0122	.0021	.0101	.0351	.0096	.0255
Ether extract.....	.0065	.0008	.0057	.0034	.0007	.0027	.0053	.0009	.0044
Nitrogen-free extract....	1.1955	.1297	1.0658	.6899	.0647	.6252	.9218	.3011	.6207
Value of gain (+) or loss (−) in weight.....	+4			+1			None.		

	Experiments with oats.								
	Chicken A ³ .			Chicken B ² .			Chicken C ² .		
	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Organic matter.....	1.1577	0.4135	0.7442	1.4907	0.4829	1.0078	0.9268	0.3681	0.5587
Crude proteid.....	.0233	.0053	.0180	.0300	.0077	.0223	.0186	.0054	.0132
Ether extract.....	.0035	.0006	.0029	.0045	.0009	.0036	.0028	.0006	.0022
Nitrogen-free extract....	.6129	.1841	.4287	.7894	.1974	.5920	.4908	.1708	.3200
Value of gain (+) or loss (−) in weight.....	−1.75			+.25			−2		

	Experiments with oats.								
	Chicken C ³ .			Chicken E.			Chicken F.		
	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.	In- come.	Outgo.	Assimi- lation.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Organic matter.....	0.8410	0.2741	0.5669	1.0846	0.3884	0.6962	0.6032	0.2165	0.3867
Crude proteid.....	.0169	.0023	.0136	.0275	.0075	.0200	.0121	.0039	.0082
Ether extract.....	.0026	.0004	.0022	.0033	.0005	.0028	.0018	.0003	.0015
Nitrogen-free extract....	.4453	.1193	.3260	.5744	.1664	.4080	.3195	.0897	.2298
Value of gain (+) or loss (−) in weight.....	−2.5			−2			−2.25		

^aWith corn at 60 cents, oats at 40 cents, and wheat at 80 cents per bushel.

TABLE XI.—*Cost of the principal nutrients—Continued.*

	Experiments with oats.			Experiments with wheat.		
	Chicken H.			Chicken A ⁴ .		
	Income.	Outgo.	Assimila- tion.	Income.	Outgo.	Assimila- tion.
	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
Organic matter	0.9482	0.3260	0.6222	1.3733	0.2204	1.1529
Crude proteid	.0297	.0086	.0211	.0223	.0050	.0173
Ether extract	.0018	.0003	.0015	.0007	.0003	.0004
Nitrogen-free extract	.4655	.1274	.3381	.9440	.1047	.8393
Value of gain (+) or loss (−) in weight	−2.5			−1		

TABLE XII.—*Daily body weight in feeding experiments with corn, oats, wheat, and beef.*

	Experiments with corn.								
	(1) Chick- en A ¹ .	(2) Chick- en B ¹ .	(3) Chick- en C ¹ .	(4) Chick- en D.	(5) Chick- en G.	(6) Chick- en 1 ¹ .	(7) Chick- en 1 ² .	(8) Chick- en 2 ¹ .	(9) Chick- en 2 ² .
	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.
First day	3 6	3 1	3 15	4 2½	2 13½	2 9½	2 8½	2 11	2 11½
Second day	3 8	3 1	3 14½	4 2½	2 13	2 10	2 8½	2 13	2 13
Third day	3 8½	3 ½	3 14½	4 3	2 13	2 10	2 9	2 12	2 12½
Fourth day	3 9	3 ½	3 14	4 3	2 13	2 10	2 9	2 12	2 12½
Fifth day	3 9½	3 1	3 14½	4 5	2 13	2 10	2 9	2 12	2 12
Sixth day	3 9½	3 1½	3 14½	4 5	2 12½	2 11	2 9½	.....	.....
Seventh day	3 10	.....	.....	4 6	2 12½	2 10½	2 9	.....	.....
Eighth day	3 12½	.....	.....	4 6	2 12½	2 10½	2 8½	.....	.....
Ninth day	3 12½	.....	.....	.....	2 12½	.....	.....	.....	.....
Tenth day	3 12½	.....	.....	.....	.....	.....	.....	.....	.....
Eleventh day	3 13	.....	.....	.....	.....	.....	.....	.....	.....
Twelfth day	3 13½	.....	.....	.....	.....	.....	.....	.....	.....
Thirteenth day	3 13½	.....	.....	.....	.....	.....	.....	.....	.....

	Experiments with corn.				Experiments with oats.				
	(10) Chick- en 3 ¹ .	(11) Chick- en 3 ² .	(12) Chick- en 4 ¹ .	(13) Chick- en 4 ² .	(14) Chick- en A ² .	(15) Chick- en A ³ .	(16) Chick- en B ² .	(17) Chick- en C ² .	(18) Chick- en C ³ .
	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.
First day	2 5	2 0	2 7½	2 ½	3 9½	3 9½	3 3	3 10	3 8
Second day	2 5½	2 1	2 7½	2 1	3 10	3 9	3 2½	3 10½	3 5
Third day	2 5	2 0	2 7½	2 1	3 11	3 8½	3 2½	3 9	3 5
Fourth day	2 6	2 0	2 9½	2 0	3 1½	3 8½	3 2½	3 9	3 5
Fifth day	2 7	2 0	2 10	1 15½	3 10	3 8½	3 3	3 8½	3 5
Sixth day	2 7	2 0	2 9	1 15	3 10½	3 8	3 2½	3 9	3 5
Seventh day	2 7	2 0	2 9½	2 0	3 11	3 8	3 3	3 8½	3 5½
Eighth day	2 7	2 0	2 9½	2 0	3 9½	3 7½	3 3½	3 8	.....
Ninth day	2 7	2 ½	2 9½	1 15½	3 11	.....	3 3½	.....	.....
Tenth day	2 7	2 ½	2 9½	2 1	3 9½	.....	.....	.....	.....
Eleventh day .....	.....	.....	2 9½	2 1	3 9½	.....	.....	.....	.....
Twelfth day .....	.....	.....	2 9	2 ½	3 9½	.....	.....	.....	.....
Thirteenth day .....	.....	.....	2 9	2 0	3 9½	.....	.....	.....	.....
Fourteenth day .....	.....	.....	2 9	2 0	.....	.....	.....	.....	.....

TABLE XII.—*Daily body weight in feeding experiments with corn, etc.*—Continued.

	Experiments with oats.					Experiments with wheat.		Experiments with beef.	
	(19) Chick- en E.	(20) Chick- en F.	(21) Chick- en H.	(22) Chick- en I ^a .	(23) Chick- en 1 ^a .	(24) Chick- en A ^a .	(25) Chick- en 2 ^a .	(26) Chick- en M.	(27) Chick- en N.
	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.	Lbs. oz.
First day	3 7	2 3½	3 3½	2 0	2 4½	3 9½	2 10	3 5	3 7
Second day	3 7½	2 3½	3 2	2 2½	2 3½	3 9½	2 10	3 4½	3 7
Third day	3 6½	2 3½	3 3	2 2	2 3½	3 9	2 10	3 4	3 6½
Fourth day	3 6	2 2½	3 2½	2 2½	2 3	3 9	2 10	3 3	3 6
Fifth day	3 6½	2 2½	3 2	2 2½	2 3	3 8½	2 10	3 5½	3 5½
Sixth day	3 5½	2 1½	3 2	2 2½	.....	3 9½	2 9	3 5½	3 5½
Seventh day	3 5	2 1	3 1	2 2	.....	3 9	2 9	.....	.....
Eighth day	3 5	2 ½	3 1	.....	.....	3 8½	2 8½	.....	.....
Ninth day .....	.....	.....	3 ½	.....	.....	.....	2 8½	.....	.....
Tenth day .....	.....	.....	.....	.....	.....	.....	2 8	.....	.....
Eleventh day .....	.....	.....	.....	.....	.....	.....	2 8	.....	.....
Twelfth day .....	.....	.....	.....	.....	.....	.....	2 8	.....	.....
Thirteenth day .....	.....	.....	.....	.....	.....	.....	2 7½	.....	.....
Fourteenth day .....	.....	.....	.....	.....	.....	.....	2 7	.....	.....
Fifteenth day .....	.....	.....	.....	.....	.....	.....	2 5	.....	.....

NOTE.—Experiments Nos. 1 to 5, 14 to 21, 24, 26, and 27 are by Brown; Nos. 6 to 13, 22, 23, and 25 by Clark.

TABLE XIII.—*The consumption and excretion of SiO₂.*

	Total SiO ₂ ingested.	Total SiO ₂ excreted.	Per cent SiO ₂ of total excre- ment.
	Grams.	Grams.	
Chicken A ¹ .—Corn	8.60	7.41	3.76
Chicken B ¹ .—Corn	(a)	6.07	7.81
Chicken C ¹ .—Corn	(a)	4.49	5.22
Chicken D. —Corn	28.09	14.60	10.08
Chicken A ² .—Oats	31.92	45.27	14.85
Chicken A ³ .—Oats	52.10	48.24	22.11
Chicken B ² .—Oats	31.50	45.80	20.57
Chicken C ² .—Oats	(a)	19.03	11.24
Chicken C ³ .—Oats	64.38	44.80	28.48
Chicken E. —Oats	27.44	32.75	17.38
Chicken F. —Oats	None.	3.64	3.98
Chicken H. —Oats	None.	5.69	4.01
Chicken G. —Corn	None.	.40	.57
Chicken A ⁴ .—Wheat	52.11	8.36	7.55

a Unobserved.

TABLE XIV.—*Excretion of SiO₂ when no sand was ingested.*

Date.	Chicken G, corn. (No sand after May 23.)		Chicken H, oats. (No sand after May 23.)		Chicken I, corn. (No sand after May 23.)	
	Total SiO ₂ in excre- ment.	Per cent SiO ₂ of to- tal excre- ment.	Total SiO ₂ in excre- ment.	Per cent SiO ₂ of to- tal excre- ment.	Total SiO ₂ in excre- ment.	Per cent SiO ₂ of to- tal excre- ment.
	<i>Grams.</i>		<i>Grams.</i>		<i>Grams.</i>	
June 1.....	0.1868	5.66	0.9633	4.94	0.3477	3.78
June 6.....	.....	.....	.....	.....	.0600	.54
June 14.....	.....	.....	.....	.....	.0951	.41
June 17.....	.....	.....	.....	.....	.0520	.38
June 19.....	.....	.....	.....	.....	.0470	.33
June 21.....	.6462	3.87	.4760	4.25	.0510	.49
July 17.....	.1064	1.33	.3894	3.81	.0520	.38

Date.	Chicken F, oats. (No sand after Feb. 26.)		Chicken M, meat. (No sand after March 27.)	Chicken N, meat. (No sand after March 27.)
	Total SiO ₂ in excre- ment.	Per cent SiO ₂ of to- tal excre- ment.	Total SiO ₂ for six days in excre- ment.	Total SiO ₂ for six days in excre- ment.
	<i>Grams.</i>		<i>Grams.</i>	<i>Grams.</i>
March 2.....	0.7172	6.52	.....	.....
March 3.....	.6450	5.45	.....	.....
March 12.....	.3300	3.11	.....	.....
April 15-20.....	.....	.....	0.4623	.....
April 15-20.....	.....	.....	.....	0.4514

BIBLIOGRAPHY.

- (1) SALKOWSKI, E. Ueber das Verhalten der Pentosen im Tierkörper. *Centralbl. f. med. Wissensch.*, Berlin, 31. J., No. 11, 18. März, pp. 193-194. 1893.
- (2) CREMER, MAX. Ueber das Verhalten einiger Zuckerarten im thierischen Organismus. *Ztschr. f. Biol.*, München & Leipzig, Bd. 29, n. F., Bd. 11, pp. 484-553. 1892.
- (3) EBSTEIN, WILHELM. Einige Bemerkungen über das Verhalten der Pentaglycosen (Pentosen) im menschlichen Organismus. *Arch. f. path. Anat. [etc.] [Virchow]*, Berlin, Bd. 129, 12. F., Bd. 9, Heft 3, 7. Sept., pp. 401-412. 1892.
- (4) SLOVZOV, B. Du sort des pentosanes dans l'organisme animal. [Russian text.] *Bull. Acad. imp. d. sc. de St.-Petersbourg*, 5. s., v. 15, No. 4, Nov., pp. 423-434. 1901.
- (5) MEISSNER, G. Beiträge zur Kenntniss des Stoffwechsels im thierischen Organismus. *Ztschr. f. rat. Med.*, Leipzig & Heidelberg, 3. R., Bd. 31, Heft 1-2, p. 216. 1868.
- (6) ROBERTS, SIR WILLIAM. The Croonian lectures on the chemistry and therapeutics of uric acid gravel and gout. *Brit. Med. Journ.*, London (1842), v. 1, June 18, pp. 1285-1290. 1892.
- (7) VON SCHRÖDER, W. Ueber die Bildungsstätte der Harnsäure im Organismus. *Arch. f. Anat. u. Physiol.*, Leipzig, *Physiol. Abth.*, Suppl.-Bd., 23. Dec., pp. 113-146. 1880.
- (8) ZALESKY, NICOLAUS. Untersuchungen über den uraemischen Process und die Function der Nieren. iv, 70 pp., 4 pls. 8°. Tübingen. 1863.
- (9) MINKOWSKI, O. Ueber den Einfluss der Leberexstirpation auf den Stoffwechsel. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 21, Heft 1, 24. Feb., pp. 41-87. 1886.
- (10) MINKOWSKI. Ueber die Ursachen der Milchsäureausscheidung nach der Leberexstirpation. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 31, Heft 2-3, 11. Apr., pp. 214-221. 1893.
- (11) LANG, S. Ueber die Stickstoffausscheidung nach Leberexstirpation. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 32, Heft 3-4, 27. Apr., pp. 320-340. 1901.
- (12) KOWALEWSKI, KATHARINA; AND SALASKIN, S. Ueber die Bildung von Harnsäure in der Leber der Vögel. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 33, Heft 1-2, 7. Aug., pp. 210-222. 1901.
- (13) MENDEL, LAFAYETTE B.; AND JACKSON, HOLMES C. On the excretion of kynurenic acid. *Amer. Journ. Physiol.*, Boston, v. 2, No. 1, Nov. 22, pp. 1-28. 1898.
- (14) PATON, D. NOËL. Studies of the metabolism in the dog before and after removal of the spleen. *Journ. Physiol.*, London, (1899-1900), v. 25, No. 6, Nov. 12, pp. 443-461. 1900.
- (15) LO MONACO, D. Osservazioni sull' escrezione e sulla formazione dell' acido urico nell' organismo. *Schmidt's Jahrb.*, Leipzig, Bd. 252, No. 2, pp. 109-110. 1896.
- (16) VON MACH, W. Ueber die Umwandlung von Hypoxanthin in Harnsäure im Organismus der Vögel. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 23, Heft 1-2, 12. Mai, pp. 148-149. 1887.
- (17) MINKOWSKI. Untersuchungen zur Physiologie und Pathologie der Harnsäure bei Säugethieren. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 41, Heft 6, 20. Dec., pp. 375-420, pls. 1-2. 1898.

- (18) BURIAN, RICHARD; AND SCHUR, HEINRICH. Ueber die Stellung der Purinkörper im menschlichen Stoffwechsel. *Arch. f. d. ges. Physiol.*, Bonn, Bd. 80, Heft 6-7, 17. Mai, pp. 241-343. 1900.
- (19) KRÜGER, MARTIN; AND SCHMID, JULIUS. Die Entstehung der Harnsäure aus freien Purinbasen. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 34, Heft 5-6, 25. Feb., pp. 549-565. 1902.
- (20) MILROY, T. H. Acid poisoning in birds. *Journ. Physiol.*, London, (1901-1902), v. 27, *Proc. Physiol. Soc.*, pp. xii-xiv. 1901.
- (21) WIENER, HUGO. Ueber Zersetzung und Bildung der Harnsäure im Thierkörper. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 42, Heft 5-6, 29. Juni, pp. 375-398. 1899.
- (22) SCHULTZEN, O.; AND NENCKI, M. Die Vorstufen des Harnstoffs im thierischen Organismus. *Ztschr. f. Biol.*, München, Bd. 8, Heft 1, pp. 124-146. 1872.
- (23) SALKOWSKI, E. Ueber den Vorgang der Harnstoffbildung im Thierkörper und den Einfluss der Ammoniaksalze auf denselben. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 1, Heft 1-2, pp. 1-59. 1877.
- (24) VON KNIERIEM, W. Beiträge zur Kenntniss der Bildung des Harnstoffs im thierischen Organismus. *Ztschr. f. Biol.*, München, Bd. 10, Heft 3, pp. 263-294. 1874.
- (25) FEDER, L.; AND VOIT, E. Zur Harnstoffbildung aus pflanzensauren Ammoniaksalzen. *Ztschr. f. Biol.*, München & Leipzig, Bd. 16, Heft 2, pp. 179-197. 1880.
- (26) LOHRER, JULIUS. Ueber den Uebergang der Ammoniaksalze in den Harn. *Diss.* 37 pp. 8°. Dorpat. 1862.
- (27) MEYER, HANS; AND JAFFÉ, M. Ueber die Entstehung der Harnsäure im Organismus der Vögel. *Ber. d. deutsche chem. Gesellsch.*, Berlin, 10. J., Juli-Dec., pp. 1930-1933. 1877.
- (28) CECI, C. O. Ueber das Verhalten des Taurins im Organismus der Vögel. *Ber. d. deutsch. chem. Gesellsch.*, Berlin, 10. J., Juli-Dec., pp. 1461-1464. 1877.
- (29) SCHRÖDER, WOLDEMARE. Ueber die Verwandlung des Ammoniaks in Harnsäure im Organismus des Huhns. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 2, Heft 4, 5. Sept., pp. 228-240. 1878.
- (30) HOPKINS, F. GOWLAND. The chemistry of the urine. *In* E. A. Schäfer's *Textbook of Physiology*, v. 1, pp. 637-638. Edinburgh & London. 1898.
- (31) BUNGE, G.; AND SCHMIEDEBERG, O. Arbeiten aus dem Laboratorium für experimentelle Pharmakologie zu Strassburg. *Arch. f. exper. Path. u. Pharm.*, Leipzig, Bd. 6, Heft 3-4, 17. Nov., pp. 233-255. 1876.
- (32) JAFFÉ, M. Ueber das Verhalten der Benzoesäure im Organismus der Vögel. *Ber. d. deutsch. chem. Gesellsch.*, Berlin, 10. J., Juli-Dec., pp. 1925-1930. 1877.
- (33) LANG, S. Ueber die Schwefelausscheidung nach Leberexstirpation. *Ztschr. f. physiol. Chem.*, Strassburg, Bd. 29, Heft 4-5, 9. Juni, pp. 305-319. 1900.
- (34) TEICHMANN, MAX. Der Kropf der Taube. *Arch. f. mikr. Anat.*, Bonn, Bd. 34, Heft 2, 30. Oct., pp. 235-247. 1899.
- (35) KLUG, F. Beitr. z. Kenntniss der Verdauung bei Vögeln. Aus dem Hauptbericht des II. Intern. Ornith. Congr. Budapest. 1890. [Reference from *Arch. f. d. ges. Physiol.*, Bd. 80, Heft 11-12. 1900.]
- (36) HUNTER, JOHN. Observations on certain parts of the animal economy. 3 p. l., 225 pp., 18 pls. 4°. London. 1786.

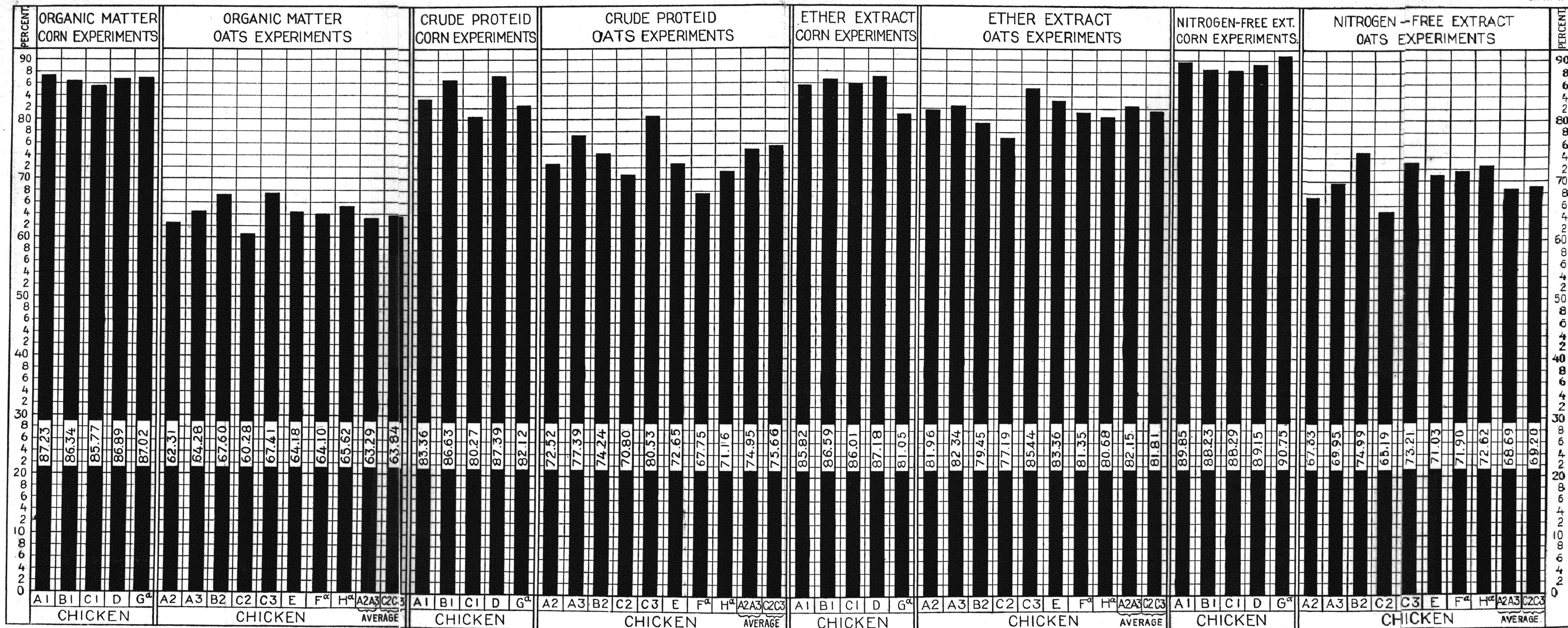
- (37) HASSE, C. Ueber den Oesophagus der Tauben und das Verhältniss der Secretion des Kropfes zur Milchsecretion. *Ztschr. f. rat. Med.*, Leipzig & Heidelberg, 3 R., Bd. 23, Heft 1-2, pp. 101-132, pls. 7-8. 1865.
- (38) RÉAUMUR. *Histol. de l'Acad. Roy. des Sciences*, 1752, Paris 1756; erste Abhandl., p. 266; zweite Abhandl., p. 461. Zusammenfassung, p. 49. [This reference taken from *Arch. f. d. ges. Physiol.*, Bd. 80, Heft 11-12. 1900.]
- (39) SPALLANZANI. *Versuche über das Verdauungsgeschäft*. Uebersetzt von D. Chr. F. Michaelis. Leipzig. 1785. [Reference from *Arch. f. d. ges. Physiol.*, Bd. 80, Heft 11-12. 1900.]
- (40) TIEDEMANN, F.; AND GMELIN, L. *Die Verdauung nach Versuchen*. 2. Ausgabe. 2 v., 280 pp., 1 l., vi (1 l.), 279 pp. 4°. Heidelberg & Leipzig. 1831.
- (41) WILCZEWSKI, [CARL ANTON] PAUL. *Untersuchungen über den Bau der Magendrüsen der Vögel*. Diss. 30 pp., 1 l. 8°. Breslau. [1870.]
- (42) PAIRA-MALL, L. Ueber die Verdauung bei Vögeln, ein Beitrag zur vergleichenden Physiologie der Verdauung. *Arch. f. d. ges. Physiol.*, Bonn, Bd. 80, Heft 11-12, 13. Juni, pp. 600-627. 1900.
- (43) BERNARD, CLAUDE. *Mémoire sur le pancréas et sur le rôle du suc pancréatique dans les phénomènes digestifs, particulièrement dans la digestion des matières grasses neutres*. *Compt. rend. Acad. d. sc.*, Paris, Suppl. v. 1, pp. 533-534. 1856.
- (44) LANGENDORFF, OSCAR. *Versuche über die Pankreasverdauung der Vögel*. *Arch. f. Anat. u. Physiol.*, Leipzig, *Physiol. Abth.*, Heft 1-2, 18. Apr., pp. 1-35, pl. 1. 1879.
- (45) HEIDENHAIN, R. *Beiträge zur Kenntniss des Pancreas*. *Arch. f. d. ges. Physiol.*, Bonn, Bd. 10, Heft 12, 25. Juni., pp. 557-632, pl. 5. 1875.
- (46) SACC, F. (fils). *Expériences sur les parties constituantes de la nourriture qui se fixent dans le corps des animaux*. *N. Denkschrft. d. allg. schweizer. Gesellsch. f. d. ges. Naturw.*, Neuchatel, Bd. 7, 9 pp., 1845.
- (47) VOIT, C. Ueber den Stickstoff-Kreislauf im thierischen Organismus. *Ann. d. Chem. u. Pharm.*, Leipzig and Heidelberg (1862-63), 2. Suppl.-Bd., Heft 2, 19. Mai, p. 240. 1863.
- (48) WEISKE, H.; AND MEHLIS, Th. Ueber das Verhalten der Rohfaser im Verdauungsapparate der Gänse. *Landwirthsch. Versuchs-Stationen*, Berlin, Bd. 21, p. 415. 1878.
- (49) KALUGIN, J. Ueber die Wirkung feinen Grandes auf die Verdaulichkeit der Nährstoffe der Hirse bei Hühnern. *Fühling's landwirthsch. Ztg.*, Leipzig, 46. J., Heft 3, 1. Feb., pp. 85-86. 1897.
- (50) KALUGIN, J. Der Versuch der Bestimmung der Verdauungskoefficienten der Nährstoffen der Körner bei Hühner. [Russian text.] *Mém. d. l'Inst. agronom. et forestier à Nowo Alexandria, Varshav*, v. 9, livr. 3, pp. 217-257. 1896.
- (51) VON KNIERIEM, W. Der Roggen als Kraftfuttermittel. [Grost's experiments included in this paper.] *Landwirthsch. Jahrb.*, Berlin, Bd. 29, Heft 3, 22. Juni, p. 520. 1900.
- (52) FIELDS, JOHN; AND FORD, A. G. Digestion trials with chickens. *Bull. 46, Oklahoma Agric. Exper. Station, Stillwater*, May, 8 pp. 1900.
- (53) LEHMANN, F. Fütterungsversuche beitr. Ernährung von Geflügel. *Deutsche landwirthsch. Presse*, Berlin, 28. J., No. 39, 18. Mai, pp. 339-340. 1901.
- (54) PARASCHTSCHUK, SIMEON. Die Verdauung des Maïs bei Hühnern. *Journ. f. Landwirthsch.*, Berlin, 50. J., Heft 1, 9. Mai, pp. 15-32. 1902.

- (55) MEYER, HANS. Beiträge zur Kenntniss des Stoffwechsels im Organismus der Hühner. Diss. 33 pp., 1 l. 8°. Königsberg. 1877.
- (56) KIONKA, H. Entstehung und Wesen der "Vogelgicht" und ihre Beziehungen zur Arthritis urica des Menschen. Arch. f. exper. Path. u. Pharm., Leipzig, Bd. 44, Heft 3-4, 14. Juni, pp. 186-206, pl. 1. 1900.
- (57) TSCHERINOW, M. Zur Lehre von dem Diabetes mellitus. Arch. f. path. Anat. [etc.], Bd. 47, 4. F., Bd. 7, Heft 1, 7. Juni, p. 117. 1869.
- (58) PRAUSNITZ, W. Ueber den zeitlichen Verlauf der Ablagerung und des Schwindens des Glykogens. Ztschr. f. Biol., München & Leipzig, Bd. 26, n. F., Bd. 8, pp. 377-413. 1890.
- (59) HERGENHAHN, E. Ueber den zeitlichen Verlauf der Bildung resp. Anhäufung des Glykogens in der Leber und den willkürlichen Muskeln. Ztschr. f. Biol., München & Leipzig, Bd. 27, n. F., Bd. 9, pp. 215-227. 1890.
- (60) PODA, HEINRICH. Eine neue Methode der Trocknung des Koths. Ztschr. f. physiol. Chem., Strassburg, Bd. 25, Heft 3-4, 9. Juli, pp. 355-359. 1898.
- (61) GIES, WILLIAM J. An improved method of preparing and preserving meat for use in metabolism experiments. Amer. Journ. Physiol., Boston, v. 5, No. 4, May 1, pp. 235-239. 1901.
- (62) WILEY, HARVEY W. Principles and practice of agricultural analysis. v. 3, p. 23. Easton, Pa. 1897.
- (63) STUTZER, A. Untersuchungen über die quantitative Bestimmung des Protein-Stickstoffs und die Trennung der Proteinstoffe von anderen in Pflanzen vorkommenden Stickstoff-Verbindungen. Journ. f. Landwirthsch., Berlin, 28. J., Heft 1, pp. 103-123. 1880.
- (64) MALLET, J. W. Report on an investigation of analytical methods for distinguishing between the nitrogen of proteids and that of the simpler amids or amido-acids. Bull. 54, Div. Chem., U. S. Dept. Agric., Washington, 25 pp. 1898.
- (65) CHITTENDEN, R. H.; AND OSBORNE, THOMAS B. A study of the proteids of the corn or maize kernel. Amer. Chem. Journ., Baltimore, v. 13, No. 7, Oct., pp. 453-468; No. 8, Dec., pp. 529-552. 1891. v. 14, No. 1, Jan., pp. 20-44. 1892.
- (66) RICHARDSON, CLIFFORD; AND CRAMPTON, C. A. Vorläufige Mittheilung über die Zusammensetzung des Weizenkeimes und über die Anwesenheit von einer neuen Zuckerart und von Allantoin. Ber. d. deutsch. chem. Gesellsch., Berlin, 19. J., pp. 1180-1181. 1886.
- (67) FRANKFURT, S. Zur Kenntnis der chemischen Zusammensetzung des ruhenden Keims von Triticum vulgare. Landwirthsch. Versuchs-Stationen, Berlin, Bd. 47, Heft 6, p. 453. 1896.
- (68) SCHULZE, E.; AND FRANKFURT, S. Ueber das Vorkommen von Betain und Cholin in Malzkeimen und im Keim des Weizenkorns. Ber. d. deutsch. chem. Gesellsch., Berlin, 26. J., Bd. 2, pp. 2151-2155. 1893.
- (69) BARTLETT, J. M.; AND MERRILL, L. H. [Digestion experiments at Maine Agricultural Experiment Station.] Ann. Rep. Maine State College Agric., Pt. 2, Agric. Exper. Station, Augusta (1888), pp. 195-203. 1889.
- (70) JORDAN, W. H.; AND MERRILL, L. H. The coefficients of digestibility for protein. Ann. Rep. Maine State College Agric. Exper. Station, Bangor (1889), pp. 282-285. 1890.
- (71) BARTLETT, J. M. Digestion experiments. 13th Ann. Rep. Maine Agric. Exper. Station, Augusta, (1897), p. 155. 1898.

- (72) PATTERSON, H. J. Report of the chemist. 4th Ann. Rep. Maryland Agric. Exper. Station, Annapolis, (1891), p. 309. 1892.
- (73) HIS, WILHELM, JR.; AND PAUL, THEODOR. Physikalisch-chemische Untersuchungen über das Verhalten der Harnsäure und ihrer Salze in Lösungen. Ztschr. f. physiol. Chem., Strassburg, Bd. 31, Heft 1-2, 27. Nov., pp. 1-42, 64-78. 1900.
- (74) VON KNIERIEM, W. Ueber das Verhalten der im Säugethierkörper als Vorstufen des Harnstoffs erkannten Verbindungen zum Organismus der Hühner. Ztschr. f. Biol., München, Bd. 13, Heft 1, pp. 36-79. 1877.
- (75) NEUBAUER AND VOGEL. Anleitung zur qualitativen und quantitativen Analyse des Harns zum Gebrauche für Mediciner, Chemiker und Pharmaceuten. Zehnte umgearbeitete und vermehrte Auflage. Analytischer Theil. In dritter Auflage bearbeitet von Dr. H. Huppert, p. 820. 8°. Wiesbaden. 1898.
- (76) HOPKINS, F. GOWLAND. On the estimation of uric acid in urine. Journ. Path. and Bacteriol., Edinburgh and London, v. 1, No. 4, June, pp. 451-459. 1893.
- (77) JOLLES, ADOLF. Ueber eine neue zuverlässige Methode zur quantitativen Bestimmung der Harnsäure im Harn. Ztschr. f. physiol. Chem., Strassburg, Bd. 29, Heft 3, 3. Apr., pp. 222-248. 1900.
- (78) JOLLES, ADOLF. Ueber die quantitative Bestimmung der Harnsäure im Harn. Ztschr. f. physiol. Chem., Strassburg, Bd. 33, Heft 5-6, 31. Okt., pp. 542-546. 1901.
- (79) TUNNICLIFFE, F. W.; AND ROSENHEIM, OTTO. Eine neue Methode der quantitativen Harnsäurebestimmung auf volumetrischem Wege. Centralbl. f. Physiol., Leipzig & Wien, Literatur 1897, Bd. 11, No. 14, 2. Oct., pp. 434-437. 1897.
- (80) KIONKA, H. Zur Kenntniss des Stoffwechsels fleischgefütterter Hühner. Arch. internat. d. Pharmacod. et d. Thérap., Gand & Paris, v. 7, fasc. 1-2, pp. 55-64. 1900.
- (81) METHODS of analysis adopted by the Association of Official Agricultural Chemists, Nov. 11, 12, and 14, 1898. Edited by Harvey W. Wiley. Bull. 46, revised ed., Div. Chem., U. S. Dept. Agric., Washington, 86 pp. 1899.
- (82) NEUBAUER AND VOGEL. Anleitung zur qualitativen und quantitativen Analyse des Harns zum Gebrauche für Mediciner, Chemiker, und Pharmaceuten. Zehnte umgearbeitete und vermehrte Auflage. Analytischer Theil. In dritter Auflage bearbeitet von Dr. H. Huppert. p. 742. 8°. Wiesbaden. 1898.
- (83) JORDAN, WHITMAN H.; AND HALL, FRANK H. The digestibility of American feeding stuffs. Bull. 77, office of Exper. Stations, U. S. Dept. Agric., Washington, p. 89. 1900.
- (84) ST. WEISER AND ZAITSCHEK, A. Beitrag zur Kenntniss der chemischen Zusammensetzung und Bildung des Gänsefettes. Arch. f. d. ges. Physiol., Bonn, Bd. 93, Heft 3-4, 3. Dec., pp. 128-133. 1902.
- (85) BARTLETT, J. M.; AND MERRILL, L. H. [Digestion experiments at Maine Agricultural Experiment Station.] Ann. Rep. Maine State College Agric., Pt. 2, Agric. Exper. Station, Augusta, (1888), p. 98. 1889.
- (86) LADD, E. F. Report of the chemist. 8th Ann. Rep. Bd. Control N. York, Agric. Exper. Station, Albany, (1889), p. 149. 1890.

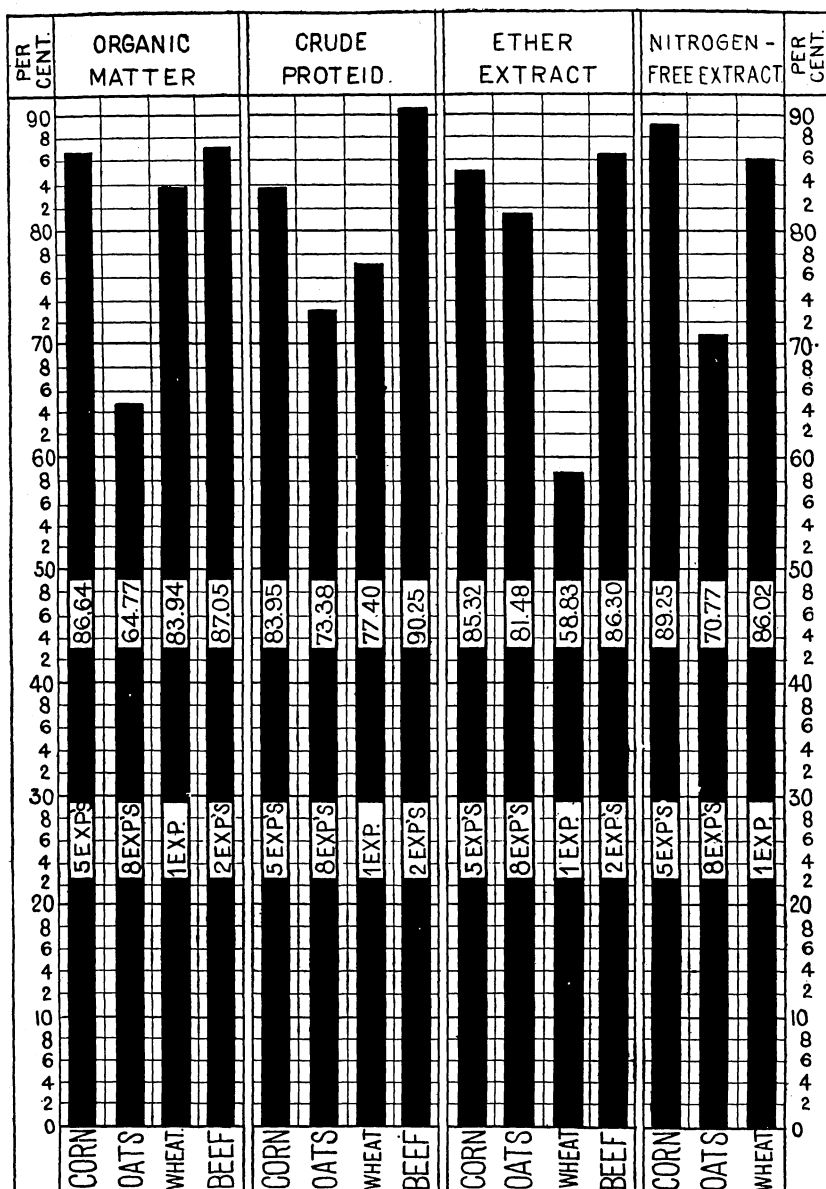
- (87) FRAPS, G. S. The digestibility of some non-nitrogenous constituents of certain feeding stuffs. Ann. Rep. No. 23, North Carolina Agric. Exper. Station, West Raleigh, (1899-1900), June 30, pp. 49-68. 1900.
- (88) SHERMAN, H. C. The insoluble carbohydrates of wheat. Journ. Amer. Chem. Soc., Easton, Pa., v. 19, No. 4, Apr., pp. 291-316. 1897.
- (89) ST. WEISER AND ZAITSCHEK, A. Beiträge zur Methodik der Stärkebestimmung und zur Kenntniss der Verdaulichkeit der Kohlenhydrate. Arch. f. d. ges. Physiol., Bonn, Bd. 93, Heft 3-4, 3. Dec., pp. 98-127. 1902.
- (90) CROSS, C. F.; BEVAN, E. J.; AND REMINGTON, J. S. On the digestion and assimilation of pentoses and furfuroids. Journ. Amer. Chem. Soc., Easton, Pa., v. 22, No. 10, Oct., pp. 630-634. 1900.
- (91) WOLFF, EMIL. Rationelle Fütterung der landwirtschaftlichen Nutztiere auf Grundlage der neueren tierphysiologischen Forschungen. 7. Aufl., neu bearbeitet von Curt Lehmann. pp. 241-245. 12°. Berlin. 1899.
- (92) ST. BONDZYŃSKI AND HUMNICKI, V. Ueber das Schicksal des Cholesterins im thierischen Organismus. Ztschr. f. physiol. Chem., Strassburg, Bd. 22, Heft 4-5, 3. Dec., pp. 396-410. 1896.
- (93) PFLÜGER, E. Ueber die Gesundheitsschädigungen, welche durch den Genuss von Pferdefleisch verursacht werden. Arch. f. d. ges. Physiol., Bonn, Bd. 80, Heft 3-5, 4. Mai, pp. 111-138. 1900.
- (94) PFEIFFER, TH. Die Bestimmung des Stickstoffs der Stoffwechselprodukte. Ztschr. f. physiol. Chem., Strassburg, Bd. 10, Heft 6, pp. 561-576. 1886.
- (95) SZUMOWSKI, W. Zein als Nährstoff. I. Mittheilung. Ztschr. f. physiol. Chem., Strassburg, Bd. 36, Heft 2-3, 6. Sept., pp. 198-218, pl. 3. 1902.
- (96) SNYDER, HARRY. The digestibility of wheat. Bull. 36, Minnesota Agric. Exper. Station, Delano, Nov., pp. 146-148. 1894.
- (97) JORDAN, WHITMAN HOWARD. The feeding of animals. p. 393. 12°. New York. 1901.
- (98) Idem. pp. 436-438.
- (99) Idem. pp. 387-388.
- (100) Idem. p. 324.
- (101) Idem. p. 359.
- (102) RICE, JAMES EDWARD. The effect on fowls of nitrogenous and carbonaceous rations. Bull. 25, Agric. Exper. Station, Cornell Univ. College of Agric., Ithaca, Dec., p. 163. 1890.
- (103) SMITH, CLINTON D.; AND BROOKS, C. S. Some experiments with poultry. Bull. 158, Michigan State Agric. College Exper. Station, May, pp. 329-344. 1898.
- (104) SMITH, CLINTON D. Report of the agriculturist. 9th Ann. Rep. Michigan State Agric. College Exper. Station, p. 109. 1896.
- (105) DRYDEN, JAMES. Poultry experiments. Bull. 67, Exper. Station Agric. College Utah, Logan, Apr., p. 142. 1900.
- (106) BROOKS, WM. P.; AND THOMSON, H. M. Report of the agriculturist. 11th Ann. Rep. Hatch Exper. Station Massachusetts Agric. College, Boston, Pub. Doc. No. 33, Jan., p. 93. 1899.
- (107) STEWART, J. H.; AND ATWOOD, HORACE. Poultry experiments. Bull. 60, W. Virginia Agric. Exper. Station, Morgantown, June, pp. 49-64. 1899.
- (108) WHEELER, W. P. The economy of using animal food in poultry feeding. Bull. 149, N. York Agric. Exper. Station, Geneva, Dec., pp. 229-248. 1898.

- (109) HALL, F. H.; AND WHEELER, W. P. What grains lack as poultry foods. Bull. 171, N. York Agric. Exper. Station, Geneva, pop. ed., Dec., 6 pp. 1899.
- (110) MALLET, J. W. The physiological effect of creatin and creatinin, and their value as nutrients. Bull. 66, Office of Exper. Stations, U. S. Dept. Agric., Washington, 24 pp. 1899.
- (111) BEILSTEIN, F. Handbuch der organischen Chemie. 3. Aufl., Bd. 1, p. 1290. (4°.) Hamburg & Leipzig. 1893.
- (112) BONGERS, [IMMANUEL AUGUST] PAUL. Ueber Synthesen im Organismus der Vögel. Diss. 1 p. l., 23 pp., 2 l. 8°. Königsberg i. Pr. 1887.
- (113) JAFFÉ, M.; AND COHN, RUD. Ueber das Verhalten des Furfurols im Stoffwechsel der Hühner. Ber. d. deutsch. chem. Gesellsch., Berlin, Bd. 21, Juli-Dec., pp. 3461-3465. 1888.
- (114) CHRISTIANI, ARTHUR. Ueber das Verhalten von Phenol, Indol und Benzol im Thierkörper. Ztschr. f. physiol. Chem., Strassburg, Bd. 2, Heft 4, 5. Sept., pp. 273-287. 1878.
- (115) SCHARY EDUARD. Beiträge zur Kenntniss des Stoffwechsels im Organismus der Vögel. Diss. 33 pp., 1 l. 8°. Königsberg. 1878.
- (116) PEUROSCH, BERTHOLD. Beiträge zur Lehre über die Entstehung des Indicans im Thierkörper. Diss. 32 pp., 1 l. 8°. Königsberg. 1877.
- (117) MÖRNER, K. A. H.; AND SJÖQUIST, J. Eine Harnstoffbestimmungsmethode. Skandin. Arch. f. Physiol., Leipzig, Bd. 2, Heft 6, 20. Jan., pp. 438-487. 1891.
- (118) SALKOWSKI, E. Ueber das Vorkommen von Allantoin im Harn nach Fütterung mit Pankreas. Centralbl. f. med. Wissensch., Berlin, Bd. 36, No. 53, 31. Dec., pp. 929-930. 1898.
- (119) MENDEL, LAFAYETTE B.; AND BROWN, ERNEST W. Observations on the nitrogenous metabolism of the cat, especially on the excretion of uric acid and allantoin. Amer. Journ. Physiol., Boston, v. 3, No. 6, Jan. 1, pp. 261-270. 1900.
- (120) CAPALDI, ACHILLE. Ein Verfahren zur quantitativen Bestimmung der Kynurensäure. Ztschr. f. physiol. Chem., Strassburg, Bd. 23, Heft 1, 27. März, pp. 92-98. 1897.



THE DIGESTION COEFFICIENTS OF THE GRAIN EXPERIMENTS.

α All chickens received sand except F, G, and H.



AVERAGE COEFFICIENTS OF ALL EXPERIMENTS.

(Continued from second page of cover.)

Dr. J. S. Kelly, care Blomer & Michael Co., Quincy, Ill.	Dr. W. H. Rose, 18 Broadway, New York, N. Y.
Dr. F. D. Ketchum, South St. Paul, Minn.	Dr. F. L. Russell, Orono, Me.
Dr. W. B. Lincoln, Union Stock Yards, Nashville, Tenn.	Dr. J. F. Ryder, 147 Milk st., Boston, Mass.
Dr. C. Loveberry, room 402, Custom House (new), Portland, Oreg.	Dr. W. A. Savage, Aurora, Ill.
Dr. H. D. Mayne, Malone, N. Y.	Dr. E. P. Schaffter, care Cleveland Provision Co., Cleveland, Ohio.
Dr. J. Miller, care John Morrell & Co., Ottumwa, Iowa.	Dr. C. A. Schaufler, 134 South Second st., Philadelphia, Pa.
Dr. C. L. Morin, St. Albans, Vt.	Dr. Thos. W. Scott, care The Rath Packing Co., Waterloo, Iowa.
Dr. A. B. Morse, care The Agar Packing Co., Des Moines, Iowa.	Dr. T. A. Shipley, care T. M. Sinclair & Co., Ltd., Cedar Rapids, Iowa.
Dr. W. J. Murphy, care Springfield Provision Co., Brightwood, Mass.	Dr. N. C. Sorenson, care Kingan & Co., Indianapolis, Ind.
Dr. W. N. Neil, care John Cudahy Co., Wichita, Kans.	Mr. Wm. H. Wade, Animal Quarantine Station Halethorp, Md.
Dr. A. J. Payne, Mason City, Iowa.	Dr. H. N. Waller, 109 West 42d st., New York N. Y.
Dr. H. D. Paxson, care Swift & Co., Fort Worth, Tex.	Dr. G. W. Ward, Newport, Vt.
Dr. F. M. Perry, Fort Fairfield, Me.	Dr. B. P. Wende, Live Stock Exchange Building, East Buffalo, N. Y.
Dr. A. J. Pistor, care New York Hotel, Fremont, Nebr.	Dr. W. H. Wray, 39 Hawarden Grove, Herne Hill, London S. E., England.
Dr. G. W. Pope, Animal Quarantine Station, Athenia, N. J.	Dr. C. H. Zink, care Western Packing Co., Denver, Colo.
Dr. H. T. Potter, Calais, Me.	
Dr. A. G. G. Richardson, room 16, Deaderick Building, Knoxville, Tenn.	